Course Code	AGR121
Course Title	Fundamentals of Agronomy
Credit Hours	**3 (2+1)**
Full Marks	**75**
Theory (Marks)	**50**
Practical (Marks)	**25**

Course Breakdown (Theory)		
SN	**Course Outline**	**Lectures**
1	**Introduction to agriculture and agronomy**	4
1.1	Definition of agriculture, Its branches, Scope of agriculture in Nepal and Agriculture practices in Nepal	1
1.2	Problems of Nepalese agriculture, Food security, reasons of food insecurity in Nepal, Agronomy and role of an agronomist in solving the food problems	1
1.3	Green Revolution, Pros and Cons of Green revolution	1
1.4	Classification of crops: Agronomic classification, based on growing seasons, and special purpose classificatio	1
2	**Weather and climatic factors affecting crop production**	4
2.1	Definition of weather, climate, meteorology and agro meteorology, elements of weather and climate, Climate and weather of Nepal	1
2.2	Solar radiation and its effects in crop production	1
2.3	Temperature and its effects in crop production	1
2.4	Precipitation, relative humidity, wind and their effect on crop growth including role of monsoon on Nepalese farming	1
3	**Crop growth and Yield**	3
3.1	Definition of crop growth, growth response curve with time, phases of crop growth, measuring the crop growth	1
3.2	Factors affecting crop growth: Leaf and canopy photosynthesis, Growth and maintenance respiration, photorespiration, abiotic and biotic stress	1
3.3	Economic and biological yield, harvest index, potential yield, attainable yield, actual yield, and National average yield; yield gap analysis and closing the yield gaps	1
4	**Soil fertility and nutrient management**	4
4.1	Soil fertility and productivity, essential plant nutrients and their classification, criteria of essentiality of plant nutrients	1
4.2	Constraints of soil fertility and productivity, management of soil productivity, Organic manures and their classification	1
4.3	Biofertilizers and their use, types of chemical fertilizers (nitrogenous, phosphatic, potassium and micronutrients)	1
4.4	Factors affecting manure and fertilizer application, Time and methods of fertilizer and manure application, Integrated nutrient management	1
5	**Seed and sowing**	2
5.1	Definition of seed, characteristics of quality seeds and its importance, Differences between seed and grain production	1
5.2	Seed germination and its types, factors effecting seed germination, Seed dormancy, Causes of seed dormancy, Different classes of seeds	1

6	**Tillage**	2
6.1	Definition, history and objectives of tillage and characteristics of good soil tilth, Types and methods of tillage: primary, secondary and inter-tillag	1
6.2	Tillage implements and their use; Conventional and conservation tillage with their advantages and disadvantages	1
7	**Irrigation and drainage**	3
7.1	Definition, objectives of irrigation, methods of irrigation: surface, subsurface, drip and sprinkler irrigation with their comparative advantages and disadvantages	1
7.2	Scheduling of irrigation: Soil moisture depletion, IW/CPE, Critical crop growth stage approaches	1
7.3	Water logging and its effects on crop growth and development, Definition and importance of drainage, types of drainage	1
8	**Weed and its management**	3
8.1	Definition of weed, Benefits of weeds, Harmful effects of weeds	1
8.2	Classification of weeds (life cycle, morphology, root system, nature of stem, dependence on host crop, family, association, special), mode of weed seed dispersal	1
8.3	Principles of weed management, methods of weed management (preventive, eradication and control methods, integrated method of weed management)	1
9	**Cropping systems**	2
9.1	Definition of monoculture, cropping pattern, cropping system, farming system, multiple cropping, sequence cropping, intercropping, mixed cropping, relay cropping, multistoried cropping	1
9.2	Requirements of multiple cropping, advantages of multiple cropping, Definition, principles and advantages of crop rotation; Cropping index, cropping intensity, land equivalent ratio	1
10	**Crop density and optimum plant population**	1
10.1	Plant ideotypes of different crops, Plant density and optimum plant population, Relation of plant density to crop yield, Factors affecting plant densities, Crop geometry	1
11	**Rain fed farming and water harvesting**	2
11.1	Difference between dryland and rain fed farming, importance of rain fed farming in Nepal	1
11.2	Management of soil moisture under moisture stress condition, water harvesting	1
Total		**30**

Course Breakdown (Practical)		
SN	**Course Outline**	**Lectures**
1	Visit to the farm nearby to identify major crops grown by the farmers	1
2	Collection and Identification of seed of field crops	1
3	Purity test and Germination test of seed	1
4	Calculation of seed rates based on germination test and purity test	1
5	Practice on selection of bold seed and seed treatment	1
6	Identification of different tillage equipment, tools and machinery	1
7	Practice on sowing of field crops	1
8	Identification of weeds and weeding of major field crops	2
9	Identification of common fertilizers used in Nepal	1
10	Calculation of manures & fertilizers for application	1
11	Practice on application of manures & fertilizers in field crops	1
12	Preparation of improved compost to preserve nutrients	1
13	Study of cropping system of nearby farmers	1
14	Maturity judging and harvesting of field crops	1
15	Study of yield attributes and yield estimation of field crops	1
Total		**15**

1 Introduction to agriculture and agronomy

Agriculture

- Agriculture is the backbone of our Nepalese Economy. About 60.4% of the total population are engaged in agriculture
- Agriculture is a very broad term encompassing all aspects of crop production, livestock farming, fisheries, forestry, etc.
- Agriculture is the most important human economic activity.
- Agriculture is the activity of man for the production of food, fiber, fuel, etc. by the optimum use of terrestrial resource i.e. land & water.

AN INTRODUCTION TO AGRICULTURE

Agriculture is derived from Latin words ***Ager*** and ***Cultura***. ***Ager*** means land or field and ***Cultura*** means cultivation. Therefore the term agriculture means cultivation of land. *i.e.*, the science and art of producing crops and livestock for economic purposes. It is also referred as the science of producing crops and livestock from the natural resources of the earth.

a. Conventional Agriculture: "Conventional Agriculture is the term for predominant farming practices and systems of crop production adapted by farmer in a particular region"

b. Ecological point of view: The process of modifying natural ecosystems to provide more goods and services for people through the nurturing of domesticated species of plants and animals; systems often use high inputs of energy in various forms.

c. General definition: The science or practice of farming, including cultivation of the soil for the growing of crops and the rearing of animals to provide food, wool, and other products.

Agriculture is an applied science which encompasses all aspects of crop production including horticulture, livestock rearing, fisheries, forestry, etc.

Agriculture is the practice of cultivating plants and livestock. Agriculture was the key development in the rise of sedentary human civilization, whereby farming of domesticated species created food surpluses that enabled people to live in cities. The history of agriculture began thousands of years ago. After gathering wild grains beginning at least 105,000 years ago, nascent farmers began to plant them around 11,500 years ago. Pigs, sheep, and cattle were domesticated over 10,000 years ago.

Types of Subsistence agriculture:

A) Shifting agriculture:

In this type of agriculture certain area of forest land is create by a combination of felling and burning (slash/burn) and crops are grown. After 2-3 years the fertility of soil is starts to decline the land is abandoned and the farmers moves to create fresh piece of another land. The land which was left previously continuous process of re-growing biomass. When enough biomass is produced and soil fertility is restored same process is repeated.

- This form of agriculture is subsistence at low population densities and is not possible where there is high population density.
- It encourage deforestation and heavy soil erosion which leads to global warming.

B) Nomadic herding (फिरन्ते पशुपालन)

In this type of farming system farming people migrate from one place to another in search of fodder for their rare, cattle, sheep, goats, camels for meat skin and wool. This type of are commonly found in west Africa, Western Asia, India (Gussars)

C) Intensive subsistence farming:

This farming system is common in density populated countries like china, India, Brazil etc. Where farmers used their small land to produce enough food for their own consumption and remaining produced is used for exchange against another goods.

- Farmers used simple tools to produce the crop.
- Farmers try to obtain maximum yield from the available land by intensive cultivation techniques.

Branches of Agriculture

1. Agronomy
2. Horticulture
3. Animal husbandry
4. Forestry
5. Fishery science
6. Agricultural Engineering and
7. Home science

1. Agronomy:

Agronomy word drive from two Greek word "Agros" means field and "Nomos" means to manage. "It is defined as an agricultural science deals with principles and practices of crop production and field management". Or "Agronomy is branch of agricultural science, which deals with principles, & practices of soil, water & crop management".

2. Horticulture:

Horticulture word drive from two Latin word "Hortus" means garden and "cultura/ Cultus" means cultivation. "Horticulture is a branch of agriculture in which deal fruit crops, vegetable crops, ornamental plants, commercial flower, medicinal crops, aromatic crops, spices crops, plantation crops, individual tree, shrub, climber and post-harvest management and processing".

3. Animal husbandry:

The word drive from "Animal" and "Husband" words. Animal means livestock and husband means one who takes care. "Animal husbandry is the branch of agriculture concerned with animals that are raised for meat, fiber, milk, eggs, or other products. It includes day-to-day care, selective breeding, and the raising of livestock".

4. Forestry:

Forestry word drive from French "Forest" word means wooded country. "Forestry is defined as the theory and practice of all that constitutes the creation, conservation and scientific management of forests and the utilization of their resources (Anon, 1966). It includes all thinking and all actions pertaining to creation and management of forests, including harvesting, marketing and utilization of all forest products and services. It includes not only management of existing forests but also the creation of new forests".

5. Fishery Science:

Aquatic and fisheries science is the study of aquatic ecosystems to increase scientific understanding and to apply basic ecological principles to their management, thereby sustaining them for multiple uses.

6. Agricultural Engineering:

It is the branch of engineering involved with the design of farm machinery, with soil management, land development, and mechanization and automation of livestock farming, and with the efficient planting, harvesting, storage, and processing of farm commodities.

7. Home Science:

Home Science can be defined as the multidisciplinary field of study that deals with health, diet, caring child, textile and garment designing, managing resources and other subjects concerned with a home.

Importance of Agriculture/Agronomy

The agriculture is summarized below.

1 Major Source of Foods

Agriculture is the primary source of food production. It kinds of various kind of staple food crops, cash crops etc.

2 Source of clothing materials

Agriculture provides fiber make cloths. About 70% of fibers come from cotton & other source of jute, wool, silk etc.

3 Major source of national Income

Agriculture is the major source of national income, which contribute about 27% of the total GDP in Nepal.

4 Source of industrials raw materials

Various type of industries such as furniture, paper, textile, handcrafts, medicine etc. are based on agriculture products.

5 Source of employments

Agriculture provides employments opportunity to about 60.4% of the working population of Nepal. Since agriculture is highly labour intensive occupation, it generated direct or indirect employment opportunity.

6 Major Source of Government revenue

Agriculture is the major source of government revenue. Land tax, registration and other payments from part of the government revenue.

7 Significance in foreign trade

Major agriculture exports of Nepal are Tea, Coffee, cardamom & medicinal herbs. This also help in earning foreign currency.

8 Environment balance

Plants liberate O_2 & animal liberate CO_2 to the atmosphere and thus the gases contribution of the atmosphere is balanced.

9 Source of food & fodder

Agriculture sector provides fodder for domestic animals. Cow provides peoples with milk which is from off provides foods.

10 Market surplus

The government of agriculture sector contributes to market surplus.

11. Increase in living standard of rural people

Other sectors of the economy i.e. industry, trade and commerce develop with the development of agriculture sector. As a consequence, it helps to increase employment and income opportunities for the people. The more income means the increased standard of living of the people.

12. Source of food and fodder

Agricultural sector provides fodder for domestic animals. Cow provides people with milk which is a form of protective food. Moreover, livestock also meets people's food requirements.

13. Importance in business

There are many businesses dependent on agriculture sector, such as chemical industries, farm equipment industries, etc. The development and advancements in agricultural sector is as a result of the development of these industries.

14. Market surplus

The growth of agricultural sector contributes to marketable surplus. Many people engage in manufacturing, as well as other non- agricultural sector as the nation develops. All these individuals rely on food production that they might meet from the nation's marketable surplus. As agricultural sector development takes place, production increases and this leads to expansion of marketable surplus.

15. Aesthetic importance

Agriculture promotes natural beauty by increasing the greenery of the surrounding. Flowers, grasses and other ornamental plants are also used for landscaping

Agronomy

Agronomy is **derived from a Greek word 'agros' meaning 'field' and 'nomos' meaning 'management'**. Principles of agronomy deal with scientific facts in relations to environment in which crop are produced.

Agronomy is the science and technology of producing and using plants by agriculture for food, fuel, fiber, chemicals, recreation, or land conservation. Agronomy has come to include research of plant genetics, plant physiology, meteorology, and soil science. It is the application of a combination of sciences such as biology, chemistry, economics, ecology, earth science, and genetics. Professionals of agronomy are termed agronomists.

Types of commercial agriculture:

i) Intensive commercial farming:

It is the system of agriculture in which large amount of capital or labour are applied to relatively smaller area of land.

ii) Extensive commercial farming:

It is the system of agriculture in which relatively small amount of capital or labour are invested to large area of land. It is practiced in terai region of southern Nepal. In this system sugarcane rice and wheat are grown.

iii) Plantation agriculture:

Plantation is a large form usually in tropical or sub-tropical countries where crops are grown for sale is distant market rather than local consumption.

Factors of commercial agriculture:

Commercial agriculture contains six key factors:

a) Location: Farms need to locate near transportation system because commercial forms must move their product to the market.

b) Climate: Farms soil as well as the climate in which farm is located determine what crop will grow and what kind of livestock can survive there.

c) Raw materials: Commercial farm totally depend on raw material, seed, fertilization animals are the examples of raw materials used in farm.

d) Labour: People who work on farm are called labour. Labour are necessary from plantation harvesting to storage of agriculture products.

e) Market:

Demand and supply are important factors for selling agriculture products. If there is high demand and less supply the price of product will be increases.

f) Transportation:

Movement of agriculture products some from to market depends on transportation system. Some crops and fruits must get to the market quickly otherwise they will damaged and farmers get losses.

Scope of Agronomy

The scope of agronomy science becomes imperative in Agriculture in the following areas.

- Identification of proper season for cultivation of wide range of crops
- Proper methods of cultivation are needed to reduce the cost of cultivation
- Proper maximize the yield and economic returns
- Availability and application of chemical fertilizers scientific use of application
- New technology to overcome the effect of moisture stress under dry land condition.
- Agronomy and future agriculture is depends on dry land agriculture
- Keeping farm implements in good shape and utilizing efficient manner
- Restoration of soil fertility, proper conservation of soil moisture
- Preparation of good seed bed
- Proper control of weeds to make land resources more productive
- New varieties of crops with high yield potential has to be exploited
- Appropriate water management practices has to be developed
- Proper methods of cultivation are needed maximize the yield and economic returns.
- The availability of herbicides for the control of weeds.
- Proper Water management agronomy crops and they play role in production.
- Intensive cropping is that the need for the day and proper time and space.
- New technology to overcome the effect of moisture stress under dry land.
- Agronomy and future agriculture depends on dry land agriculture.
- Maintaining the ecological balance through efficient management of crops, livestock.
- Proper management of agronomy crops, feedings in a rational manner are feasible only by knowing agronomic principles.

Evolution of man and Agriculture

There are different stages in development of agriculture, which is oriented with human civilization. They are Hunting Pastoral Crop culture Trade (stages of human civilization).

1. Hunting – It was the primary source of food in old days. It is the important occupation and it existed for a very long period.

2. Pastoral – Human obtained his food through domestication animals, e.g. dogs, horse, cow, buffalo, etc. They lived in the periphery of the forest and they had to feed his domesticated animals. For feeding his animals, he would have migrated from one place to another in search of food. It was not comfortable and they might have enjoyed the benefit of staying in one place near the river bed.

3. Crop culture - By living near the river bed, he had enough water for his animals and domesticated crops and started cultivation. Thus he has started to settle in a place.

4. Trade – When he started producing more than his requirement the excess was exchanged, this is the basis for trade. When agriculture has flourished, trade developed. This lead to infrastructure development like road, routes, etc.

Agriculture practices in Nepal

Nepal has more than 50% of people engaged in agriculture. Food grains contributed 76 percent of total crop production in 1988–89. In 1989-90 despite poor weather conditions

and a lack of agricultural inputs, particularly fertilizer, there was a production increase of 5 percent. Nepal is an agricultural country having 66 percent people directly engaged in farming. Farming is subsistent in nature and crop is mostly integrated with livestock. Nepal is richly endowed with agro-biodiversity. **Rice, maize, millet, wheat, barley and buckwheat are the major staple food crops**.

Agriculture & Agricultural Practices

- Soil preparation. Before raising a crop, the soil in which it is to be grown is prepared by ploughing, levelling, and manuring.
- Sowing. Selection of seeds of good quality crop strains is the primary stage of sowing. ...
- Manuring.
- Irrigation.
- Weeding.
- Harvesting.
- Storage.

Relation of agronomy to other sciences

Agronomy is a main branch of Agriculture.

It is synthesis of several disciplines like soil science, Agricultural chemistry, crop physiology, plant ecology, biochemistry and economics.

- The Soil Science helps the agronomist to thoroughly understand the soil physical, chemical and biological properties to effect modification of the soil environment.

-The Agricultural Chemistry help the agronomist to understand the chemical composition and changes involved in the production, protection, and use of crops and livestock. –

- The crop physiology helps to understand the basic life process of crops to understand functioning of each parts of plant to determine their input requirement like nutrients etc.

-The plant ecology helps us to understand the associated environment in which the crops grown like the influence of weather (Temperature, Rainfall etc.).

-The biochemistry shows the way in which biochemical process takes place in crops which helps to understand critical requirements to favorably activate this process.

- The economics paves the way for profit and loss analysis in farming.

Problems of Agriculture in Nepal

1. Non-Implementation of Government Policies

This is the root of all agricultural problems in the country. The policies the government put down has a long way in expanding the agricultural sector in the country. It is the responsibility of the government to establish strategies for the growth of agriculture in the country. In the last four years, there have been good policies created by the government to improve the agricultural productivity in the country, but the implementation of these policies has been unsatisfactory rendering the effort of the government to improve the industry useless. For example, the majority of the farmers producing the bulk of food crops consumed in Nigeria still use crude tools for farming.

2. Lack of Modernization and Mechanization

A large population of Nepal farmers is from rural areas, and the majority of them still make use of crude equipment for farming. This implies there is low substitution for labor making

farming more labor-intensive and this will inadvertently affect the productivity of the farmers. The majority of these rural farmers have no access to the modern farming equipment, and this is because the modern equipment is very expensive to purchase or even hire. To save money for themselves, the majority of them rely on their primitive tools for farming.

3. Illiteracy

There is no doubt to the fact that the literacy rate in Nepal is low. Also, the effects of illiteracy have been felt in almost every sector of the economy. One of the factors militating the growth of agriculture in Nigeria is illiteracy. The majority of Nepalese farmers lack formal education not to talk about modern agricultural education. Farmers need to understand some basic things like the best period for planting, how to select the right seeds, best on-farm practices reducing crop loss and so on.

4. Ignorance

Another problem facing agriculture in Nepal today is the ignorance of the Nepalese citizens. Agriculture is greatly undermined and overlooked by the Nepalease citizens as an odd job that is made for illiterate and rural people.

5. Lack of Funds

Insufficient financial support of farmers is a very serious issue that constitutes a major setback to the development of agriculture in Nepal. To be a successful farmer in the country, one needs money to start the business and even stay in the business because there are so many difficulties encountered by farmers which put them in situations where they need funds to enable them to expand and improve their yields.

6. Poor Infrastructure/ Lack of Social Amenities

Lack of social amenities and poor infrastructures is another issue limiting the success of agriculture in the country. As we mentioned above, most farmers in Nepal resides in remote areas, where basic amenities like water, electricity, and so on are absent which makes farming difficult for the farmers. These areas also have bad road networks which make it almost impossible for the farmers to transport their goods.

7. Absence of Modern Storage/Processing Facilities

A bulk of food crops produced in Nepal are perishable foods and studies show that about 80% of foods produced by Nepalese farmers go bad due to lack of modern storage facilities like silos, silage, barns, and so on. Some of this farm produce is also attacked by pests while others are affected by the high temperature which reduces the quality of the farm produce.

8. Loss of Land to Natural Disaster

Among all other problems of agriculture, this is the most natural and devastating because there is little or no control over it. A natural disaster such as erosion is a threat to farmers in Nepal because it destroys farmland and agricultural produce, it even renders the farmland useless for a period.

9. Access to Land and Fertilizers

Accessing lands for expanding farm is difficult in Nigeria. Most farmers just have a piece of land to the farm which leaves them no option than to farm on the same piece of land again and again which eventually result in land degradation whereby fertile lands lose most

of its nutrients and become unproductive or barren. This makes farmers depend on artificial fertilizers because they are easy to come by instead of natural, or biological fertilizers to grow crops.

10. The insecurity of Nepal Farmers
This is the most recent problem faced by farmers in Nigeria today. A large chunk of Nigerian farmers is from the northern part of the country where insecurity is high.
The majority decided to stay away from their farm to secure their lives.

Food security
Food security is a basic human right. In fact, having access to at least an adequate amount of nutritious food could be seen as the most basic of all human rights.
Food security is the measure of an individual's ability to access food that is nutritious and sufficient in quantity. Some definitions of food security specify that food must also meet an individual's food preferences and dietary needs for active and healthy lifestyles.

How is food security measured?
As we have already discussed, food security is a multi-faceted concept which begs the question, how is food security assessed? Perhaps unsurprisingly, there are several facets and methods used to assess food security.
1. Estimating calories per capita
2. Household income and expenditure surveys
3. Measuring individual's dietary intake
4. Measuring individual's height, weight and body composition
5. Reports of individual's experience of food security

The concept of food security can be broken down into four main components known as the '4 pillars of food security'.
Four pillars of food security are:
1. Food availability (sufficient food supply)
2. Food accessibility (food must be within the reach of people)
3. Food consumptability or absorption
4. And Food sustainability (there must be the sustainability in all above mentioned sectors

1 Food Availability - Availability simply refers to the existence of food within a community. This is closely linked to the efficacy of food production. Availability can become an issue when there is a lack of necessary resources, such as water for irrigation or when land being used for food production is damaged or degraded.
2 Food Access - Simply having enough food in a community means very little if there is poor access to it. True food security means that individuals have the resources they need to obtain a sufficient quality of nutritious food. Access to food is affected by a myriad of physical, social and policy related factors. Factors such as pricing, household proximity to suppliers and infrastructure all affect our access to food.
3 Food Utilization - Not all food is of equal or sufficient value. To be food secure, it is crucial that the food being accessed is of a good quality. It is paramount that food is nutritious and healthy enough to provide the energy people need for their daily activities. It is also crucial that individuals have the necessary knowledge and tools to properly 'utilize' the food available to them. This includes having the utilities to properly select, prepare, and store foods that are available and accessible.

4 Food Stability - Good food stability means that access, availability and utilization of food remains relatively stable over time. It is important to try to minimize any threats to this stability. Threats to food stability include natural disasters, climate change, conflict and economic factors such as volatile price fluctuations.

Some causes of food insecurity in Nepal are listed and explained below:
Poverty and lack of purchasing power limits the poor's ability to assess food. Even poor people are unable to consume enough food and calories required for their body, and lack of micronutrients may compromise their bodies ability to absorb and synthesize nutrients and causes different types of disease.

1. Geographical topography of Nepal :-
Nepal is biologically and geographically diversified country. Most of the areas of the country are covered by high hills and mountains, and less cultivable land for agricultural practices are available. Due to the topography of land in Nepal, people are unable to produce much crops which causes lack of food in the country.

2. Population growth :-
Population growth is one of the major problem of food insecurity in Nepal. The population of the country is increasing day by day but the agricultural land remains same which can't fulfill the required food needs of the growing population. And due to increasing population, agricultural fields are used for housing and converting into cities which causes decrease in agricultural land and yield of crops causing food insecurity in Nepal.

3. Climatic effect :-
Food production and food insecurity is heavily impacted by natural climatic condition of Nepal that includes a prolonged drought, severe flooding, frequent landslide and occasional hailstorm. Rice is one of the more severely affected crops from drought and a late monsoon. Most of the Nepalese farmer depend on rain water for their agriculture.

4. Impact of migration and mobility :-
Due to large scale migration, directly or indirectly, deteriorates the condition of food security. In case of Nepal, many youth abandoned their village and even their cities and migrate to other countries. This allowed large area of cultivable land to fallow every year. It reduces the labour intensive agricultural business.

5. Infrastructure destruction:-
There are lack of infrastructure in Nepal. Some parts of the country are deprived of roads which unable to transport food in all part of the country and causes starvation in some parts. They only consume what they grow.

6. Lack of storage facilities:
Nepal is a agricultural country so, most of the food items are obtained from agricultural fields. Agricultural products are mostly decaying in nature. They require proper storage facilities for long term use but there is very low storage and processing facilities in Nepal.

7. Food price :
Food price is also an important cause of food insecurity in the country. In countries like Nepal, the prices of food items differ according to place. It is not possible for poor to purchase enough food for their consumption. Especially the people from mountain and high hills becomes the victim of high prices.

8. Lack of technicians and technical knowledge :-
In Nepal, most of the people are engaged in traditional and subsistence agriculture system. Due to lack of technicians and technical knowledge in the country the production is decreasing. Most of the farmers have small land holdings for agriculture which causes less commercial agriculture.

9. Lack of law implementation and improper market distribution:-
Improper distribution of market causes unequal prices of same commodities according to places. And proper law are not made and implemented in country which causes unavailable of food in all part of the country.

10. Unemployment and poverty :-
Unemployment and poverty have greatly contributed in food insecurity of Nepal. In Nepal, most of the people are unemployed and they don't have equal economic status. Where, rich get enough food but poor die due to hunger.

Role of Agronomist
Agronomist is a scientist who is dealing with the study of problems of crop production and adopting/recommending practices of better field crop production and soil management to get high yield and income.
• Agronomist aims at obtaining maximum production at minimum cost by exploiting the knowledge of the basic and applied sciences for higher crop production.
• In a broader sense, agronomist is concerned with production of food and fiber to meet the needs of growing population.
• He develops efficient and economic field preparation method for sowing crops in different season. (Flat bed, Ridges and furrows)
• He is also involved to selection of suitable crop and varieties to suit or to match varied seasons and soils. Eg. Red soil - groundnut, Black soil - cotton, Sandy soil – tuberous crops, Saline soil – Finger millet (Ragi). In Kharif if water is sufficient go for rice and water is not sufficient go for maize, sorghum.
• Evolves efficient method of cultivation (whether broadcasting, nursery and transplantation or dibbling, etc.) provides better crop establishment and maintain required population
• He has to identify various types of nutrients required by crops including time and method of application (e.g. for long duration rice (150-60-60 kg NPK), short duration: 120:50:50 kg NPK/ha Application P&K basal and N in three splits)
• Agronomist must select a better weed management practice. Either through mechanical or physical (by human work) or chemical (herbicides or weedicides, e.g. 2-4-D) or cultural (by having wide space it may increase weed growth by using inter space crops). Weeds are controlled by integrated weed management method also
• Selection of proper irrigation method, irrigation scheduling i.e. irrigation timing and quantity based on the crops to be irrigated, whether to irrigate continuously or stop in between and how much water to be supplied are computed by agronomy science so as to achieve maximum water use efficiency.
• Crop planning (i.e.) suitable crop sequence are developed by agronomist (i.e.) what type of crop, cropping pattern, cropping sequence, etc. (Rice - Rice - Pulse)
• Agronomists are also develops the method of harvesting, time for harvesting, etc. (Appropriate time of harvest essential to prevent yield loss)

• Agronomist is responsible for every decision made in the farm management. (What type of crop to be produced? How much area to be allotted for each crop? How and when to market? How and When to take other management activities?) All the decisions should be taken at appropriate time to efficiently use resources available)

Green revolution

The term "Green Revolution" was first used by William S. Gaud, the administrator of the U.S. Agency for International Development (USAID), in a speech on 8 March 1968. He noted the spread of the new technologies as: "These and other developments in the field of agriculture contain the makings of a new revolution. It is not a violent Red Revolution like that of the Soviets, nor is it a White Revolution like that of the Shah of Iran. I call it the Green Revolution.

The Green Revolution spread technologies that already existed, but had not been widely implemented outside industrialized nations. Two kinds of technologies were used in the Green Revolution and aim at cultivation and breeding area respectively. The technologies in cultivation are targeted at providing excellent growing conditions, which included modern irrigation projects, pesticides, and synthetic nitrogen fertilizer. The breeding technologies aimed at improving crop varieties developed through the conventional, science-based methods available at the time. These technologies included hybrids, combining modern genetics with selections.

High-yielding varieties

The novel technological development of the Green Revolution was the production of novel wheat cultivars. Agronomists bred cultivars of maize, wheat, and rice that are the generally referred to as HYVs or "high-yielding varieties". HYVs have higher nitrogen-absorbing potential than other varieties. Since cereals that absorbed extra nitrogen would typically lodge, or fall over before harvest, semi-dwarfing genes were bred into their genomes.

Green revolution, great increase in production of food grains (especially wheat and rice) that resulted in large part from the introduction into developing countries of new, high-yielding varieties, beginning in the mid-20th century. Its early dramatic successes were in Mexico and the Indian subcontinent. The new varieties require large amounts of chemical fertilizers and pesticides to produce their high yields, raising concerns about cost and potentially harmful environmental effects. Poor farmers, unable to afford the fertilizers and pesticides, have often reaped even lower yields with these grains than with the older strains, which were better adapted to local conditions and had some resistance to pests and diseases. *See also* Norman Borlaug.

Green Revolution Pros

So, the revolution succeeded in providing enough food for everyone while bringing about some other benefits, which I've listed below.

1. Increased Food Production

This is one of the most significant achievements of the Green Revolution. In 2005, the UN speculated that we would need to increase our food crop yields by 70% to feed our population by 2050.

2. Consistent High Yields in Unfavorable Conditions

Before the Green Revolution, farmers relied on Mother Nature when it came to annual yields and produce. However, scientists and researchers succeeded in creating new strains of various crops, including wheat and rice, during the revolution.

3. Low Food Prices

Anyone who has an idea about how basic economics works would know that the higher the supply, the lower the price gets. That's why, as the croplands worldwide became more productive, attributing to the green revolution, food became relatively cheaper than it was before.

4. Environmental Sustainability

Before the Green Revolution, the only way to increase food crop yields was to use more land for farming. This meant converting forests and **wetlands** into farmlands.

5. Improved Immunity in Plants

Furthermore, plants are no longer as vulnerable as they used to be at the beginning of the 18th century. During the Green Revolution, scientists created numerous strains of staple food crops.

6. Reduced Need for Fallowing

Fallowing was a common farming technique used to make farmlands productive throughout the year. This technique involved enhancing the moisture level during a particular season if the region's precipitation level was low.

7. Accurate Harvest Predictions

One way the Green revolution has made life easier for farmers is by allowing them to predict their harvest correctly. Initially, the yields used to depend on the season.

8. The Greenhouse Technique

Researchers developed the greenhouse technique to control the climate using LED lights, fans, and vertical farming during the Green Revolution.

Green Revolution Cons

1. Green Revolution Crops Are Dependent on Fertilizer

Borlaug and many other scientists involved in the Green Revolution **received the Nobel Prize** for discovering new strains of food crops. These crops helped produce higher yields needed to meet the global food demand.

2. Adverse Effects on the Environment

While the Green Revolution contributed to environmental well-being in some ways, it has adverse effects as well. For example, fertilizers, pesticides, and other chemical compounds released into the **air increased pollution**.

3. Increased Food Waste

Ironically, after the Green Revolution, we ended up having way more food than required to sustain the human population. Now that farmers worldwide are concentrating on producing more yield to gain more profit, there's a lot of food wastage in the entire process.

4. Seed Sterility

As a consequence of the Green Revolution, some farmers produce yields with sterile seeds. This means they cannot plant another harvest unless they purchase patented fertile seeds from a commercial company.

5. Global Expenditure

Although using technologies and techniques from the Green Revolution does produce high yields, it also requires high initial investments. Initially, all farmers would need was seeds, water, and some cattle to achieve yearly harvests.

6. Exponential Rise in the Production of Cash Crops

Using the Green Revolution techniques to produce higher yields, farmers are focusing on cash crops to generate more revenue.

7. The Green Revolution Is Not the Solution We Were Looking For

Unfortunately, The Green Revolution did not serve its purpose entirely. The initiative was taken to resolve world hunger and grow enough food to sustain the global population. Yet, we're far from solving the food crisis for good.

Even today, malnutrition and hunger remain the

So, the revolution succeeded in providing enough food for everyone while bringing about some other benefits, which I've listed below.

While starting this list of Green Revolution pros and cons, first of all, let's look at the bright side. If it weren't for the Green Revolution, we as humans would be facing strict food rationing, inflation, and even famine in various countries worldwide.

Importance of classifying the Crop Plants

1. To get acquainted with crops.
2. To understand the requirement of soil & water different crops.
3. To know adaptability of crops.
4. To know the growing habit of crops.
5. To understand climatic requirement of different crops.
6. To know the economic produces of the crop plant & its use.
7. To know the growing season of the crop
8. Overall to know the actual condition required to the cultivation of plant.

CLASSIFICATION OF CROPS:

A. Use/Agronomic classification:

1. Grain crops: may be cereals as millets cereals are the cultivated grasses grown for their edible starchy grains. The larger grain used as staple food is cereals. E.g. rice, Jowar, wheat, maize, barley, and millets are the small grained cereals which are of minor importance as food. E.g. Bajara.

2. Pulse/legume crops: seeds of leguminous crops plant used as food. On splitting they produced dal which is rich in protein. E.g. green gram, black gram, soybean, pea, cowpea etc.

3. Oil seeds crops: crop seeds are rich in fatty acids, are used to extract vegetable oil to meet various requirements. E.g. Groundnut, Mustard, Sunflower, Sesamum, linseed etc.

4. Forage Crop: It refers to vegetative matter fresh as preserved utilized as food for animals. Crop cultivated & used for fickler, hay, silage. Ex- sorghum, elephant grass, guinea grass, berseem & other pulse bajara etc.

5. Fiber crops: crown for fiber yield. Fiber may be obtained from seed. E.g. Cotton, steam, jute, Mesta, sun hemp, flax.

6. Roots crops: Roots are the economic produce in root crop. E.g. sweet, potato, sugar beet, carrot, turnip etc.

7. Tuber crop: crop whose edible portion is not a root but a short thickened underground stem. E.g. Potato, elephant, yam.

8. Sugar crops: the two important crops are sugarcane and sugar beet cultivated for production for sugar.

9. Starch crops: grown for the production of starch. E.g. tapioca, potato, sweet potato.

10. Dreg crop: used for preparation for medicines. E.g. tobacco, mint, pyrethrum.
11. Spices & condiments/spices crops: crop plants as their products are used to flavor taste and sometime color the fresh preserved food. E.g. ginger, garlic, chili, cumin onion, coriander, cardamom, pepper, turmeric etc.
12. Vegetables crops: may be leafy as fruity vegetables. E. g. Palak, mentha, Brinjal, tomato.
13. Green manure crop: grown and incorporated into soil to increase fertility of soil. E.g. sun hemp.
14. Medicinal & aromatic crops: Medicinal plants includes cinchona, isabgoli, opium poppy, senna, belladonna, rauwolfra, licorice and aromatic plants such as lemon grass, citronella grass, palmers, Japanese mint, peppermint, rose geranicem, jasmine, henna etc.

B. Classification Based on growing season:
1. Kharif/Rainy/Monsoon crops: The crops grown in monsoon months from June to Oct-Nov, Require warm, wet weather at major period of crop growth, also required short day length for flowering. E.g. Cotton, Rice, Jowar, bajara.
2. Rabi/winter/cold seasons crops: require winter season to grow well from Oct to March month. Crops grow well in cold and dry weather. Require longer day length for flowering. E.g. Wheat, gram, sunflower etc.
3. Summer/Zaid crops: crops grown in summer month from March to June. Require warm day weather for major growth period and longer any length for flowering. E.g. Groundnuts, Watermelon, Pumpkins, Gourds.

C. Classification of Crops based on Special Purpose
This classification is used to refer to plants having special advantages to the farmer himself in relation to his farming practices. In special purpose classification, crops are divided into 11 categories. They are:
Crop plants, which are grown with the intension of serving special purposes in addition to obtaining yield or to meet a particular purposes.
a) Catch crops: Catch crops are cultivated to catch the forthing season. They replace as main crop that has failed due to biotic or climatic or management hazards and utilize the remaining period of the season. They are generally of very short duration, quick growing or usable at any time. eg. green gram, blackgram. cowpea, coriander, onion etc.

b) Restorative crops: Crops which provide a good harvest along with enrichment of the soil. eg. legumes. They fix atmospheric N in root nodules, shed their leaves during ripening and restore soil condition.

c) Paira crops or relay crops: Crops which are grown a few days or weeks before the harvesting of the standing mature crop. These crops are grown on residual moisture without preparatory tillage. eg. lentil or khesari broadcasted in paddy field, fingermillet transplanted in maize field.

d**) Smother crops:** Those crops which are able to suppress the population and growth of weeds by providing suffocation (curtailing movement of air) and obscuration (of the incidental radiation) by their dense foliage due to quick growing ability with heavy tillering and branching. eg. barley, mustard, cowpea etc.

e) Cover crops: Those crop plants which are able to protect the soil surface from erosion (wind, water or both) through their ground covering foliage or root mats eg. groundnut, marvel grass, black gram, rice bean, sweet potato etc.

f) Nurse crops: Crops plants which help in the nourishment of other crops by providing shade and acting as climbing sticks eg. rai crop in peas, crotolaria in tea.

g) Trap Crops: Crops plants, which are grown to trap soil borne harmful biotic agents such as parasitic weeds, orobanche and striga that are trapped by solanaceous and sorghum crops respectively. These weed seeds germinate when they came in contact with roots of these crops.

h) Mulch crops: Crops plants which are grown to conserve soil moisture from bare ground by their thick and multilayered foliage eg. cowpea.

i) Sod crops: These plants are grown to conserve soil from erosion particularly in non-arable areas. eg. Cynodon doctylon (Dubo grass), marvel grass.

j) Cash crops: These crops plants are grown for sale to earn hard cash eg. Jute, cotton and sugarcane etc.

k) Silage crops: These crops plants are grown to preserve in silo pit in a succulent condition by a process of natural fermentation for feeding livestock during lean months.

l) Green manuring crops: These crops plants are grown to be incorporated it into the soil fresh to increase the fertility of the soil eg. Dhaincha, sunnhemp etc.

m) Mixed crops: these crops consist of two or more crops that are grown simultaneously in the same field without preserving their identity with respect to field area. Seed of these crops may be mixed together before sowing and broadcasted irregularly or may be sown at the same time and grown with the same management practices eg. maize + cowpea, wheat + mustard.

n) Intercrops: These consist of two or more crops that are grown simultaneously in alternate rows in the same field. eg. sugarcane + wheat, maize + soybean.

o) Mono or sole crop: Crops, which are grown as pure or solid stands are called mono crops. eg. transplanted rice, jute, tobacco etc.

p) Ratoon crop: This refers to the subsequent harvests taken from the regrowth of the root stocks, stubbles and stumps after the first harvest eg. sugarcane, napier, berseem, oats etc.

q) Alley crops: When arable crops are grown in alleys formed by trees or shrubs, established mainly to hasten soil fertility restoration, enhance soil productivity and reduce soil erosion they are known as alley crops eg. Eucalyptus, Cassia, Subabool etc.

D. Classification based on life of crops/duration of crops:

1. Seasonal crops: A crop completes its life cycle in one season-Karin, Rabi. Summer. E.g. rice, Jowar, wheat etc.

2. Two seasonal crops: crops complete its life in two seasons. E.g. Cotton, turmeric,

ginger.
3. Annual crops: Crops require one full year to complete its life in cycle. E.g. sugarcane.
4. Biennial crops: which grows in one year and flowers, fructifies & perishes the next year? E.g. Banana, Papaya.
5. Perennial crops: crops live for several years. E.g. Fruit crops, mango, guava etc.

E. Classification based on cultural method/water:
1. Rain fed: crops grow only on rain water. E.g. Jowar, Bajara, Mung etc.
2. Irrigated crops: Crops grows with the help of irrigation water. E.g. Chili, sugarcane, Banana, papaya etc

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F. Classification based on root system:
1. Tap root system: The main root goes deep into the soil. E.g. Tur, Grape, Cotton etc.
2. Adventitious/Fiber rooted: The crops whose roots are fibrous shallow & spreading into the soil. E.g. Cereal crops, wheat, rice etc.

G. Classification based on economic importance:
1. Cash crop: Grown for earning money. E.g. Sugarcane, cotton.
2. Food crops: Grown for raising food grain for the population and & fodder for cattle. E.g. Jowar, wheat, rice etc.

H. Classification based on No. of cotyledons:
1. Monocots or monocotyledons: Having one cotyledon in the seed. E.g. all cereals & Millets.
2. Dicots or dicotyledonous: Crops having two cotyledons in the seed. E.g. all legumes & pulses.

I. Classification based on photosynthesis' (Reduction of CO2/Dark reaction):
1. C3 Plants: Photo respiration is high in these plants C3 Plants have lower water use efficiency. The initial product of C assimilation in the three 'C' compounds. The enzyme involved in the primary carboxylation is ribulose-1,-Biophospate carboxyl's. E.g. Rice, soybeans, wheat, barley cottons, potato.

2. C4 plants: The primary product of C fixation is four carbon compounds which may be malice acid or acerbic acid. The enzymes responsible for carboxylation are phosphoenol pyretic acid carboxyl's which has high affinity for CO2 and capable of assimilation CO2 event at lower concentration, photorespiration is negligible. Photosynthetic rates are higher in C4 than C3 plants for the same amount of stomata opening. These are said to be drought resistant & they are able to grow better even under moisture stress. C4 plants translate photosynthetic rapidly. E.g. Sorghum, Maize, natter grass, sesame etc.

3. Cam plants: (Cassulacean acid metabolism plants) the stomata open at night and large amount of CO2 is fixed as a malice acid which is stored in vacuoles. During day stomata are closed. There is no possibility of CO2 entry. CO2 which is stored as malice acid is broken down & released as CO2. In these plants there is negligible transpiration. C4 & cam plant have high water use efficiency. These are highly drought resistant. E.g. Pineapple, sisal & agave.

J. Classification based on length of photoperiod required for floral initiation:
1. Short-day plants: Flower initiation takes plate when days are short less than ten hours. E.g. rice, Jowar, green gram, black gram etc.
2. Long day's plants: require long days are more than ten hours for floral ignition. E.g. Wheat, Barley,
3. Day neutral plants: Photoperiod does not have much influence for phase change for these plants. E.g. Cotton, sunflower.

K) Classification based on climate:
1 Tropical: Crops grow well in warm & hot climate i.e. in terai region of Nepal. E.g. Rice, sugarcane, Jowar etc.
2 Sub-tropical: Crops grow in hilly region of Nepal. E.g. Rice, Wheat, Millet etc
3 Temperate: Crops grow well in cool climate. E.g. Wheat, Oats, Gram, Potato etc.

L) According to the method of harvesting
1) Reaping (cut on the basal portion of the crop): rice, mustard, sugarcane etc.
2) Uprooting by pulling: tori, lentil, linseed, blackgram, radish etc.
3) Uprooting by digging: potato, onion, garlic, ginger, sweetpotato, colocasia, groundnut, carrot etc.
4) Picking: Cotton, brinjal, gourds, maize,chillies etc.
5) Priming: tobacco
6) Cutting: Oats, napier, berseem, amaranthus, spinach etc.
7) Grazing: paragrass, pasture grasses etc.

M) According to post harvest but pre processing requirements
1) Curing: tobacco, mustard, sesame etc.
2) Stripping: jute, sunnhemp, flax etc.
3) Shelling: groundnut, maize, sunflower etc.
4) Ginning: cotton
5**) Seasoning**: Turmeric, chillies etc.
6) Grading and storing: Potato, rice, wheat, fibre crops, tobacco etc

Climate region of Nepal
1 Hot (Tropical): Crops grow well in warm & hot climate. Temperature up to> 24^0C in summer. The area between 70-1000m above sea level. I.e. in terai region of Nepal. Their production Mango, Rice, sugarcane, Jowar etc.
2 Sub-tropical: Crops grow in hilly region of Nepal. It temperature up to 17-24^0C in summer. The area between 1000-1500m above sea level. This region production Citrus fruit, Rice, Wheat, Millet etc.
3Mild temperate: Crops grow well in cool climate. Hear temperature 10-15^0C. Range between 1500-2200m altitudes. Hear production Pear, Wheat, Oats, Gram, Potato etc.
4 Temperate: In this region pronounced wit forest and snow fall. Average temperature 10^0c -0c winter season. The altitude range 2200-3200m in sea level. Hear region production Apple, potato, walnut etc.
5 Tundra –In this region all season snow fall and Altitude Sea level in 3200m above area.

2 Weather and climate:

Weather refers to the state of the atmosphere in the short term (hourly , daily or week) in terms of variations in temperature ,humidity ,precipitation ,cloudiness , radiation ,visibility , and air turbulence within local area (like village ,city or even a district) .Weather is what is presented on daily TV or radio broadcasts like sunny days ,rainy days ,amount of rainfall , maximum and minimum temperature ,humidity etc.

Weather –weather refers to state of the atmospheric in the short term several of humidity, temperature, rainfall etc. With local area in presented on day TV, Radio broadcast like day.

Climate –Climate is a generated weather of summation of weather condition over given region during a comparatively longer period. Climate is larger area.
Macro climate-Micro climate is refers to the climate of restively large part of earth.
Micro climate-Micro climate is part of it in inner part (small area) or outside in larger plant or hill.

Climate:

Climate is a generalized weather or summation of weather conditions over a given region during a comparatively longer period. Climate is a weather conditions related to larger areas like zone, state, country or part of continent and for longer period like month, season or year .Examples of climates are tropical, subtropical, temperate climate etc.

Macro climate refers of relatively larger part of the earth surface which is observed and recorded by network of meteorological stations and forms the basis for the characterization of zonal and regional climates .

Microclimate refers to the weather conditions of plant stand from the upper surface of the stand down to the deepest roots in the soil .It is characteristics climate ,determined by the type and height of the plant cover .It is also influenced by the climatic elements .

Metrology is the science that deals with laws and principle as they apply to atmospheric phenomenon .It is the science of atmospheric and its attendant activities.

Agro metrology is the science that deals the metrology in relation to agricultural activities. Climate is an important environmental factor for plant growth .It governs the extent of plant distribution and sets the limits for the survival of plants .The major factors influencing climate are latitude ,altitude and large bodies of water .The temperature of a place decreases roughly by 1^{o} c with in altitude of 100 m .The large bodies of water moderate the temperature of the location .The location near and far from the equator receives different amount of solar radiation which cause variation in climate .

Causes of climate change are following;

A) **Natural cause:**

The climate change through natural causes.it include;

1) **Volcanic eruption:-**When a volcano erupts it throws large volume of SO2 gas, H2O vapour, dust and ash mixed into atmosphere that cause climate change.

2) **Global warming:-** The temperature of earth increase day by day due to global warming which directly climate change.

3) **Earthquake:-** This cause resent change in surround environment through mixing dust,ash and different gasses.

4) **Ocean current**:- it moves large amount of heat across the earth.

5) **Variation in solar radiation receive:-** it can't seen short time but change in radiation in longer time period which is major cause of climate cause.

6) **Earth orbital change:-** The earth makes one full orbit around the sun each year, when it changes, the radiation effect to earth become adverse and change climate.

7**) Natural disaster**:- Drought, snow fall, storm etc are directly affect climate condition.

B) Human causes:
Human cause means which cased by human that affect climate, these are,

1) De-forestation/ Forest fire:- it means reduce of forest component where tree are help in
neutralizaing harmful gases and maintain climate status.

2) Industrialization:- industry are establish more rapidly day to day it produce many waste product that affect climate change. e.g- petrol/ desel industry produce more gasses.

3) Population growth:- de-forestation is mainly caused by population growth.

4**) Excessive use of chemical**:- Now a days chemical are used in every where in agricultural,missile test , industry etc which direct affect climate change.

5**) Green house gasses:-**Now a days human produce excessive amount of greenhouse gasses. it is
main cause of man made where they produce these from industry and different ways these are;
• CO2- carbon dioxide is largest driver of green house effect.
• Methane & NO- These are produce from agricultural field I.e, rice cultivation and animal farming.
• The other greenhouse gasses are CO, NO2, chlorofluorocarbon etc.
These above gasses act as barrier of solar radiation escape from earth and increase atmosphere temperature and affect climate.

The major elements of climate are:
1. Solar radiation
2.Temperature
3.Precipitation
4.Relative humidity
5.Wind
6. Hailstone
7. Frost

Solar radiation:

Solar radiation, often called the solar resource or just sunlight, is **a general term for the electromagnetic radiation emitted by the sun**. Solar radiation can be captured and turned into useful forms of energy, such as heat and electricity, using a variety of technologies.

Although the solar corona is a source of extreme ultraviolet and X-ray radiation, these rays make up only a very small amount of the power output of the Sun (see spectrum at right). The spectrum of nearly all solar electromagnetic radiation striking the Earth's atmosphere spans a range of 100 nm to about 1 mm (1,000,000 nm). This band of significant radiation power can be divided into five regions in increasing order of wavelengths:

1 Ultraviolet C or (UVC)

UVC range, which spans a range of 100 to 280 nm. The term *ultraviolet* refers to the fact that the radiation is at higher frequency than violet light (and, hence, also invisible to the human eye). Due to absorption by the atmosphere very little reaches Earth's surface. This spectrum of radiation has germicidal properties, as used in germicidal lamps.

2 Ultraviolet B or (UVB)

UVB range spans 280 to 315 nm. It is also greatly absorbed by the Earth's atmosphere, and along with UVC causes the photochemical reaction leading to the production of the ozone layer. It directly damages DNA and causes sunburn. In addition to this short-term effect it enhances skin ageing and significantly promotes the development of skin cancer, but is also required for vitamin D synthesis in the skin of mammals.

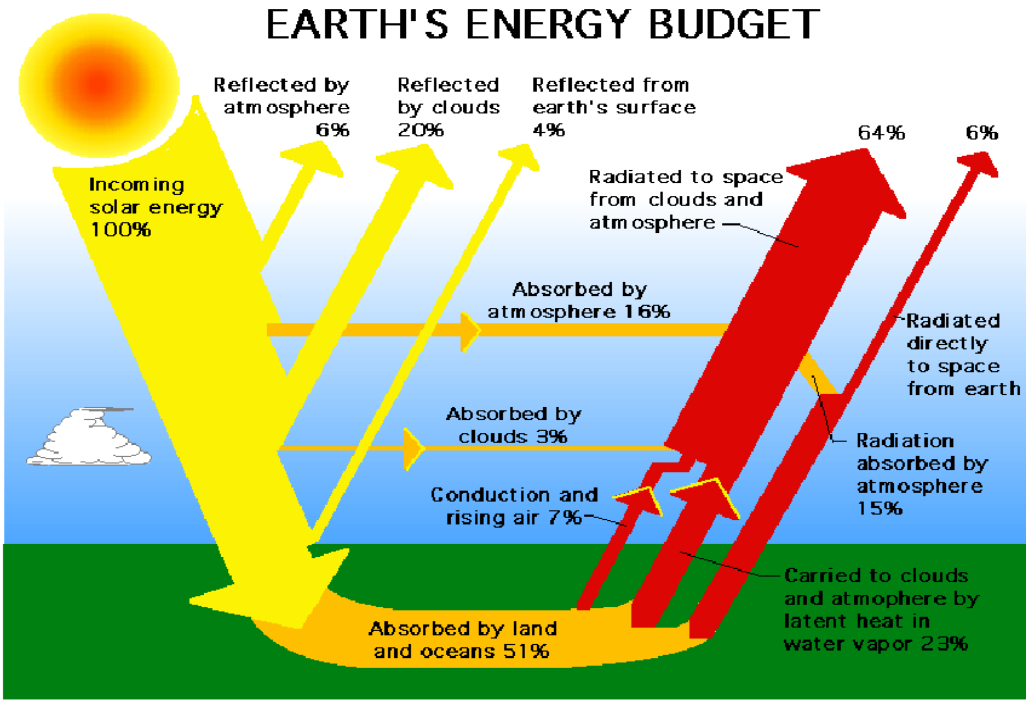
3 Ultraviolet A or (UVA)

UVA spans 315 to 400 nm. This band was once held to be less damaging to DNA, and hence is used in cosmetic artificial sun tanning (tanning booths and tanning beds) and PUVA therapy for psoriasis. However, UVA is now known to cause significant damage to DNA via indirect routes (formation of free radicals and reactive oxygen species), and can cause cancer.

- **Visible range** or **light** spans 380 to 700 nm. As the name suggests, this range is visible to the naked eye. It is also the strongest output range of the Sun's total irradiance spectrum.
- **Infrared** range that spans 700 nm to 1,000,000 nm (1 mm). It comprises an important part of the electromagnetic radiation that reaches Earth.

Scientists divide the infrared range into three types on the basis of wavelength:

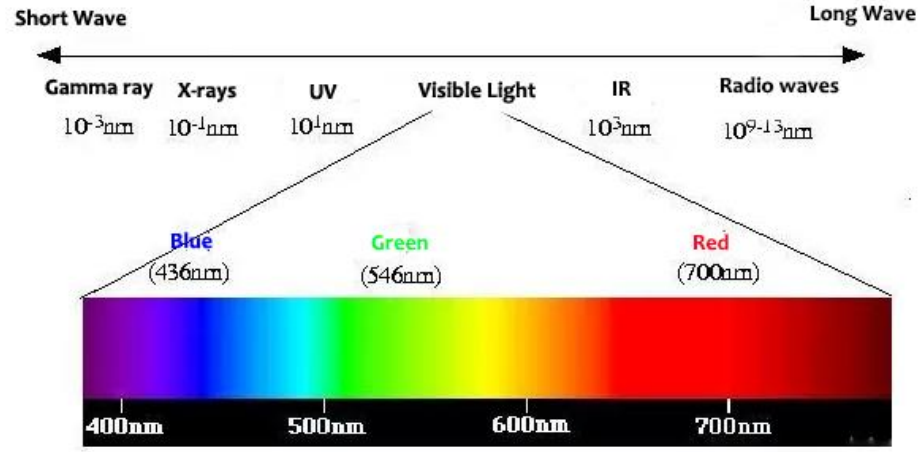
- Infrared-A: 700 nm to 1,400 nm
- Infrared-B: 1,400 nm to 3,000 nm
- Infrared-C: 3,000 nm to 1 mm.



Solar energy provides light required for

1 Seed germination,
2 Leaf expansion,
3Growth of stem and shoot,
4 Flowering,
5 Fruiting and
6 Thermal conditions necessary for the physiological functions of the plant.

Solar radiation plays an important role as regulator and controller of growth and development.



Visible light

The visible light spectrum is the segment of the electromagnetic spectrum that the human eye can view. More simply, this range of wavelengths is called visible light.

Visible light 380-700 nm

Quality of light

Blue light and red light can promote the opening of stomata, while the green light can close stomata. Blue light can improve the development of chloroplast, complex light of red, blue and green lights can expand leaf area, and red light can increase the accumulation of photosynthesis production.

400-500nm (blue violent
650-700nm (red)

QUANTITY OF LIGHT

The meaning of QUANTITY OF LIGHT is luminous energy that is the product of mean luminous flux by time. How to use quantity of light in a sentence.

The radiant energy that comes from the sun on the earth surface is called radiation .The biosphere receives solar radiation at wavelength ranging from 290 nm to about 10^5 nm .The major factors influencing the amount of solar radiation at particular location are the latitude season and time of the day .The effect of solar radiation on plant growth can be divided into four distinct groups.

1. Photosynthesis effect of solar radiation
2. Photoperiodic effect
3. Thermal effect
4. Other effect

Photosynthesis effect:

The solar radiation reaching on the plant communities in the range of wave length between 400nm.700nm are most efficiency used in photosynthesis .This range of solar radiation is called photosynthesis active radiation (PAR) .The energy of lower wave length is higher than energy of higher wave length .Because pigment excitation is a direct result of interaction between a photon and the pigment (chlorophyll) a measure of light used in photosynthesis is often based on photon flux density rather than energy .Photon flux density is the number of photons striking a given surface per unit of time .The photon flux density within the range of PAR is called photosynthesis photon flux density (PPFD) .The unit used to measure PPFD in international system of unit is μ mol m^{-2} s^{-1} .There are other units used to measure light also like foot candle(fc), lux (lx) , Langley ,watt etc. are but they are now used less frequently .The response of photosynthesis to light intensity is termed as light response curve .Photosynthesis increase with increasing light intensity up to light saturation point ,thereafter it became constant .

Affect in plant =100-380 NM (Ultraviolent light
Quality of Light= 400-500 Nanometer (Blue violent) Vegetative growth
650-700 Nanometer (Red) Flowering

The enzymes responsible for photosynthesis are rubisco and PEP carboxylase .Higher light intensity increase activity and amount of these enzymes .Besides that the infrastructure of photosynthesis like chlorophyll, leaf area and their expose are govern but light intensity.

Photoperiodic effect:

The time during which any plants are exposed to sunlight is known as photoperiod .The response of plant to photoperiod is known as photoperiods. Plants produce flowering in response of photoperiod .Plants are classified into group based on photoperiod requirement of flowering. They are:

Long day plants:

The plants require longer days (>12 hrs photoperiod) for flowering are called long day plant. Example: Wheat, barley and oat.

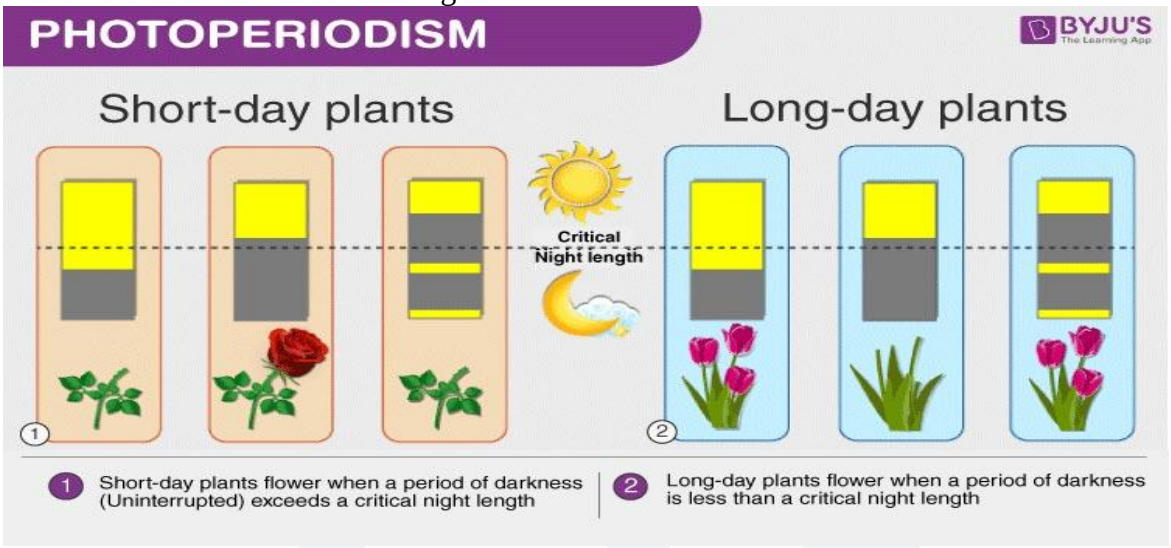
Short day plant:

The plants that require short day length (<12 hrs photoperiod) for flowering are known as short day plants .Example: Rice, maize and soybean.

Day neutral plants:

The plants that have no effect of photoperiod on flowering are known as day neutral plants. Example: Sunflower, cotton and buckwheat.

Short day and long day crops are season bound but scientists have develop many verities of crops which are photo periodically ,insensitive and can be grown any time of year if other factors which are not limiting .



Other effect:

A) Assimilation of nutrients:

- Utilization of nitrogen by plants is higher in light than in dark.
- Uptake of potassium is higher in barley under higher light density.
- Accumulation of phosphorus is higher in maize in light than in dark.

B) Seed dormancy and germination:

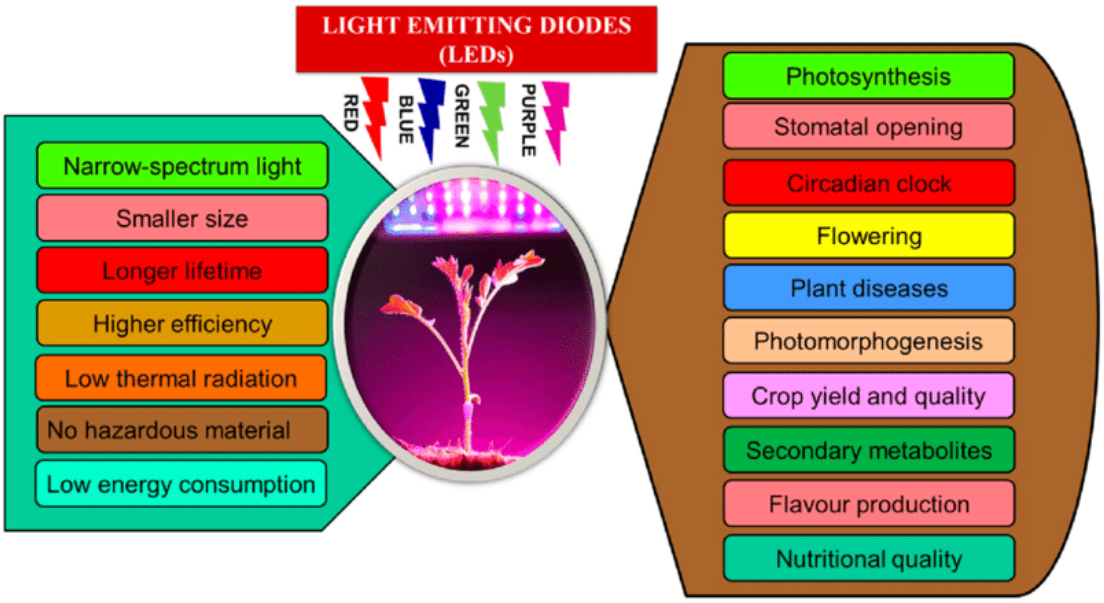
- Seeds of some of plant species such lettuce and tobacco (photoblastic plants) do not germinate in absence of light.
- Seeds of onion and amaranthus (Non photoblastic) will remain dormant if exposed to light.

C) Stomatal movement:

- In many plants stomata open under normal light condition but in CAM plant (pineapple) stomata open only in nights.
- Stomatal opening determine gas exchange and transpiration.

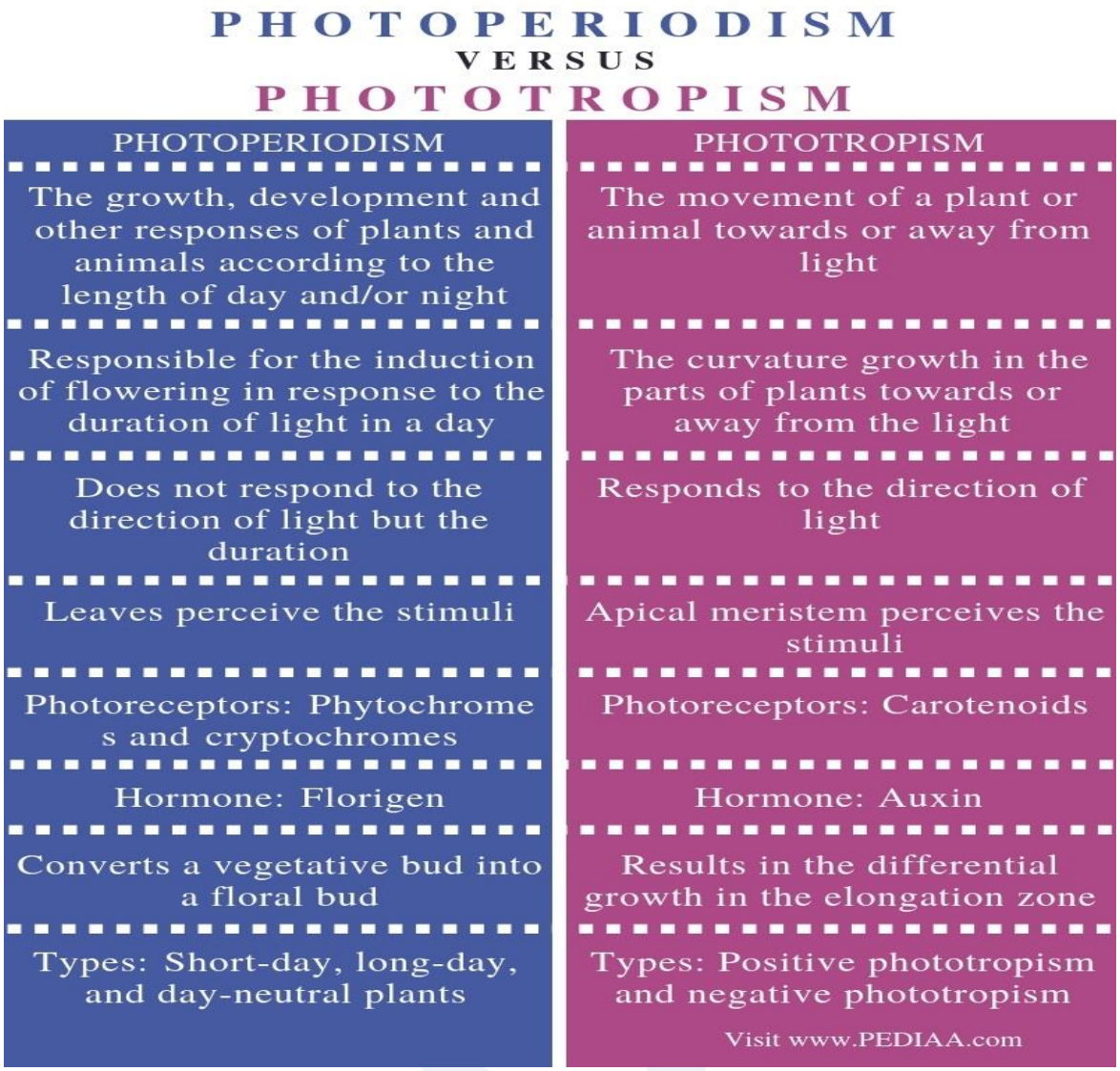
d) Etiolation and bareness:

- Plants growing in low light intensity or in dark or in closer spacing are longer and weak. .In an attempt to receive light , these plants grow spindly .Shading increases auxin (IAA) levels .Shaded plants have excessive stem elongation (prone to lodging) .
- Plants growing under low light intensity have more barren spikelets because of reduced grain filling.



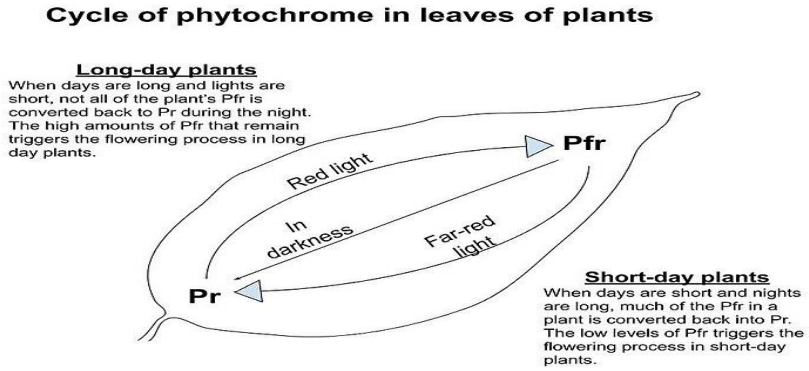
(*b*) *Phototropism and photoperiodism*

	Phototropism	*Photoperiodism*
1.	It is the response of plant towards light.	It is response of plants to the relative length of day and night period to induce flowering.
2.	It acts through the photo oxidation of auxins.	It acts through the interplay of photosynthesis.
3.	All plants exhibit similar types of response to the direction of light.	Plants exhibit different responses on the basis of their photoperiodic response.
4.	The stimulus is perceived by apical meristem.	The leaves perceive the stimulus.
5.	Phototropic movements are produced only in the presence of blue light.	Photoperiod movements are produced only in the presence of red light.



What is Photoperiodism

Photoperiodism is the physiological response of plants to the length of the day or night. Generally, the light or dark periods are known as **photoperiods**. Moreover, these photoperiods are responsible for the conversion of vegetative buds into flower buds in plants. Photoreceptor proteins such as phytochromes or cryptochromes in leaves play a critical role in sensing the lengths of the night lengths. Furthermore, based on the developing response, there are three types of plants: short-day plants, long-day plants, and day-neutral plants.



What is Phototropism

Phototropism is the growth of a part of a plant in response to the direction of the light. Generally, the hormone responsible for the growth is auxin. Basically, it is responsible for regulating the elongation of the newly differentiated cells at the tips of both stem and root. Moreover, based on the direction of the elongation in response to light, there are two types of phototropism. They are positive and negative phototropism.

1 Positive Phototropism

Positive phototropism occurs in the apex of the stem. Generally, it is responsible for the growth of the stem apex towards the light. However, when the plant receives directional sunlight, auxin in the apical meristem tends to gather in the shaded side, resulting in the higher elongation of cells in the shaded side compared to the bedazzling side. It, in turn, bends the tip of the stem towards the light source.

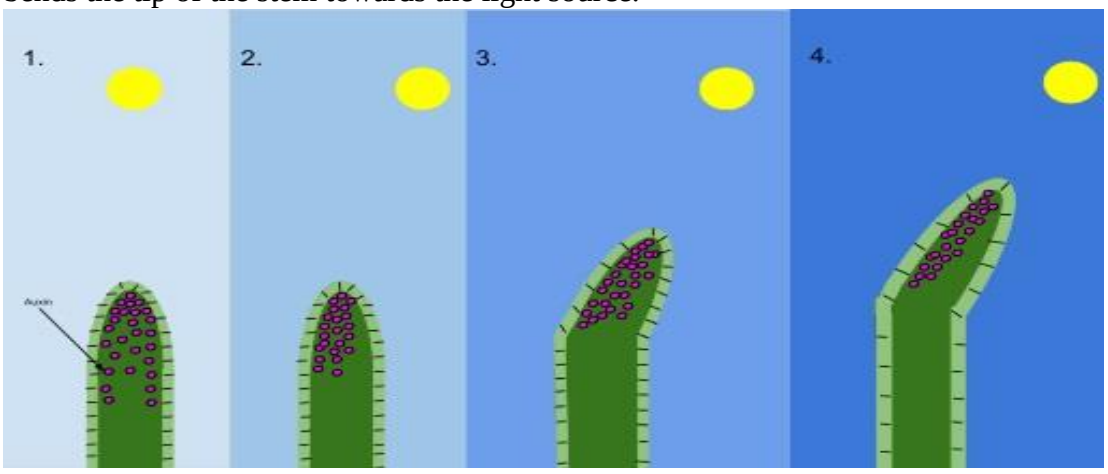
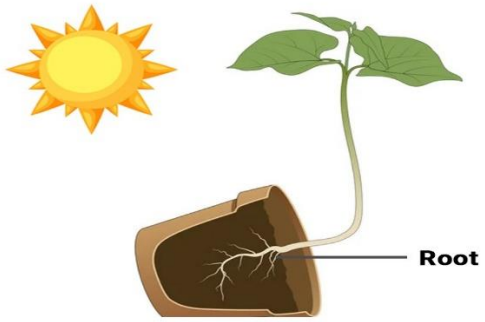


Figure 2: Positive Phototropism

2 Negative Phototropism

The apex of the root shows negative phototropism as it grows away from the light source. Normally, this is due to the concentration of auxin at the bottom side of the root, elongating cells in the apex into the soil.



Negative Phototropism

Temperature

Temperature is the degree of hotness and coldness of a substance and is measured in Celsius scale (^oC) in metric system.

Solar radiation that comes on the earth surface is converted into heat energy.

T**emperature** is a physical quantity that expresses hot and cold or a measure of the average kinetic energy of the atoms or molecules in the system.

This is major contributing factor for the temperature of plants and its environment .The latitude, altitude and distance from large of water bodies of water determine the temperature of the location.

Cardinal temperature: For each plant species there are lower minimum temperature (T_{min}) and upper maximum temperature (T_{max}) at which growth is nil or negligible .The temperature which is most favorable for plant growth is the optimum temperature (T_{opt}). T_{min} , T_{max} and T_{opt} are called cardinal temperature .

Cardinal temperature

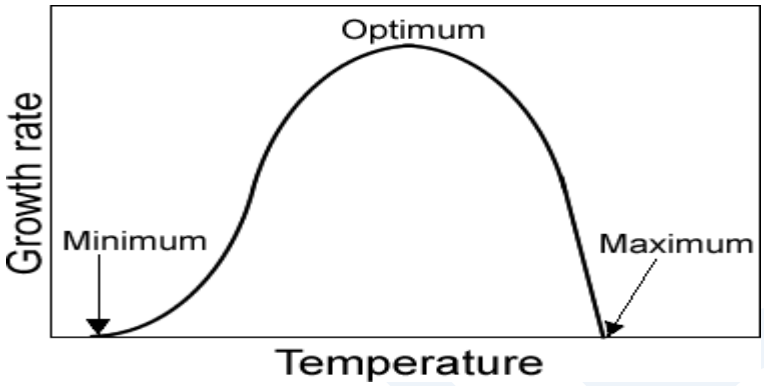
The minimum cardinal temperature is the lowest temperature at which crop growth can occur; this temperature is referred to as the base temperature, and no growth occurs below this temperature. The optimum cardinal temperature is the temperature at which crop growth and performance are at their maximum.

Cardinal temperature of some of crops:-

Temperature ^oC

Crops	Minimum	Optimum	Maximum
Rice	10	32	38
Wheat	5	25	32
Maize	10	32	43
Soybean	5	25	35
Potato	5	20	30

Crops	Minimum	Optimum	Maximum
Oat	4 - 5	25	30
Maize	8 - 10	32 - 35	40 - 44
sorghum	8 - 10	32 - 35	40
Pearl millet	8 - 10	30 - 32	40
Berseem	3 - 4.0	25 - 27	32
Wheat	3 - 4.5	25	30
Rice	10 - 12	30 - 32	36 - 38



Effect of biochemical reactions:-

There are biochemical processes which are affected by the temperature .the rate of reaction for every 10c increase in temperature is called quotient 10.

Rate of reaction at (t + 10^{o}C) Q10

Rate of reaction at t^{o} c

This concept was develop to compare the effects of temperature increase on plant metabolic process .In general, the rate of process increases with increase in temperature from T_{min} and decrease rapidly after increase in temperature from T_{opt} .This is because increase in temperature increase the velocity of enzymes from T_{min} and T_{opt} .As there is further increase in temperature the enzymes structure is damaged and rate of reaction is decreased.

Effect of Temperature in crop production

High temperature, even for short period, affects crop growth especially in temperate crops like wheat. High air temperature reduces the growth of shoots and in turn reduces root growth. High soil temperature is more crucial as damage to the roots is severe resulting in substantial reduction in shoot growth.

Climate is the most important dominating factor influencing the suitability of a crop to a particular region. The yield potential of the crop mainly depends on climate. More than 50 per cent of variation of crops is determined by climate. The most important climatic factors that influence growth, development and yield of crops are solar radiation, temperature and rainfall.

1) Low temperature:

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

Chilling injury	If the plants grown in hot temperature are exposed to low temperature, they will be killed (or) severely injured. When the

	night temperature is below 15°C field crops may show yellowing symptoms (eg) Tropical annuals.
Freezing injury	When the plants are exposed to how temperature, water freezes into ice crystals in the intercellular spaces. (eg) Cell dehydration Temperate crops (potato, tea etc.,)
Suffocation	Formation of thick cover of ice/snow on the soil surface presents the entry of oxygen and crop suffers. This presents the respiration and lead to accumulation of harmful substances.
Heaving	Lifting of plants along with soil from its actual position by ice, crystals. This is a mechanical lifting.

Frost damage:

Low temperature near the canopy due to earth's re-radiation. If the cell size is large the probability of frost damage is high.

(1) Advective frosts

Advective frosts are due to incursion of large masses of cold air over a region from the colder areas.

(2) Radiation frost:

Occur on clear calm nights when heat is freely radiated from all exposed objects.

(i) Hoar frost (or) white frost:

This is caused due to sublimation of ice crystals on objects like tree branches.

(ii) Black frost:

The vegetation is frozen because of reduction of air temperature.

Plant management against frost damage:

1. Frost free growing season
2. Adjusting the sowing time
3. Selection of resistant varieties
4. Sprinkler irrigation

2 HIGH TEMPERATURE INJURIES

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

1. The critical temperature above which plants gets killed is called thermal 'death point'.
2. The temperature above 50°C may kill many annual crops. –
3. The limit varies with plants; shade loving plants are killed at lower temperature.

Mineral Nutrition

1. High temperature stress causes reduction in absorption and subsequent assimilation of nutrients.
2. Absorption of calcium is reduced at temperature of 28º C in Maize.
3. Nutrient uptake is affected by both soil and air temperature in rice.
4. Nitrate reductase activity decrease under high temperature.

Shoot growth

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

3. High soil temperature is more crucial as damage to the roots is severe resulting in substantial reduction in shoot growth.
4. High temperature at 38º C in rice reduced plant height, root elongation and smaller roots.

Pollen development

1. High temperature during booting stage results in pollen abortion.
2. In wheat, temperature higher than 27º C caused under-development of anthers and loss of viability of pollen.
3. A temperature of 30º C for two days at reduction division stage decreased grain yield by drastic reduction in grain set.

Scorching:

High temperature lead to dehydration and leaves are scorched.

Physiological activities:

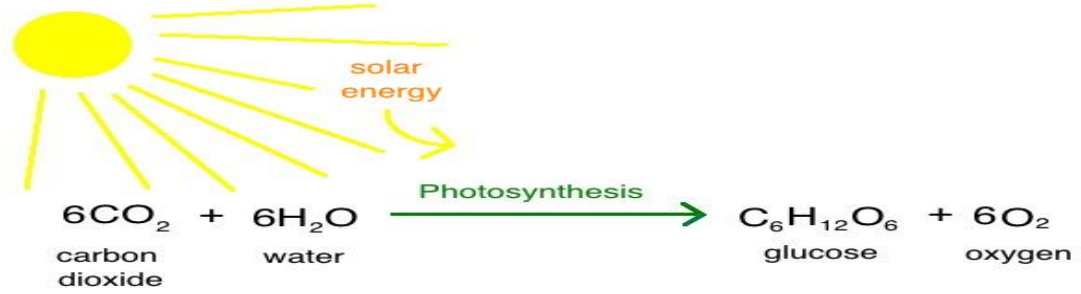
High temperature disturbs the photosynthesis and respiration.

Burning off:

The symptoms are noticed on young seedlings due to high soil temperature. The seedlings are killed.

3 Effect on photosynthesis

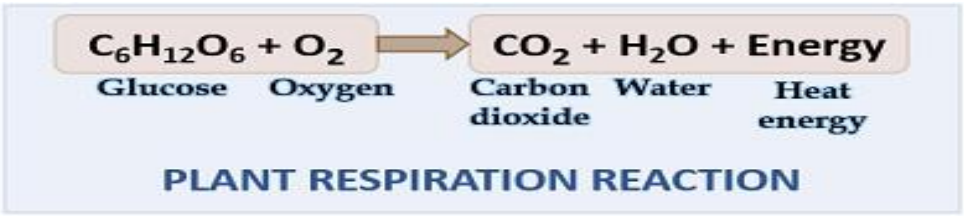
Photosynthesis is the process by which plants use sunlight, water, and carbon dioxide to create oxygen and energy in the form of sugar.



Photosynthesis also decline after optimum temperature .The net photosynthesis is the highest at optimum temperature and lower at both ends of optimum temperature. Temperature has considerable influence on chlorophyll synthesis and leaf area development. Temperature enhances the production of chloroplasts .At low temperature, leaves become yellow due to degradation of chlorophyll.

4 Respiration

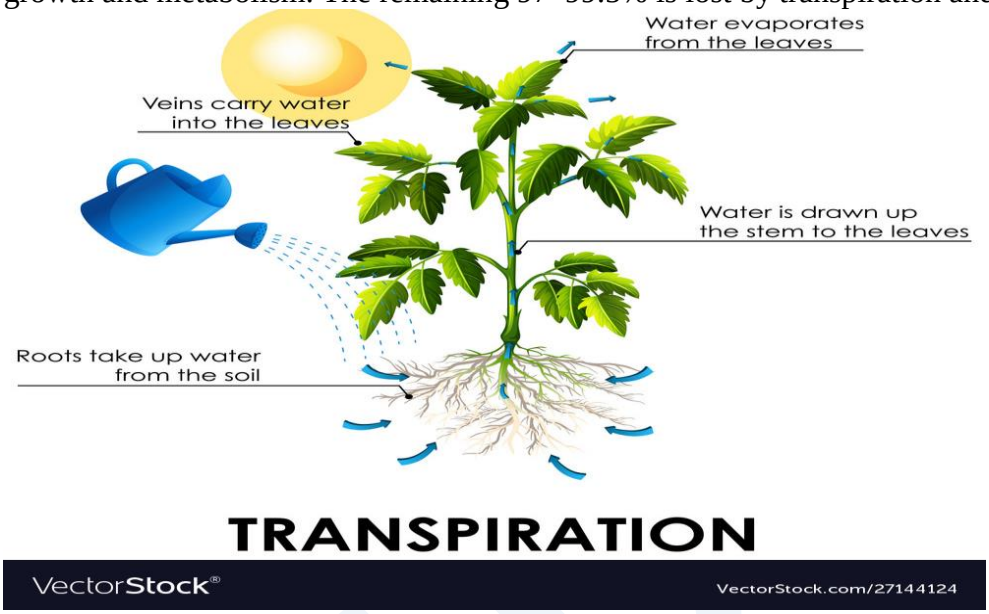
The process of respiration in plants involves using the sugars produced during photosynthesis plus oxygen to **produce energy for plant growth**. In many ways, respiration is the opposite of photosynthesis. In the natural environment, plants produce their own food to survive.



5 Transpiration

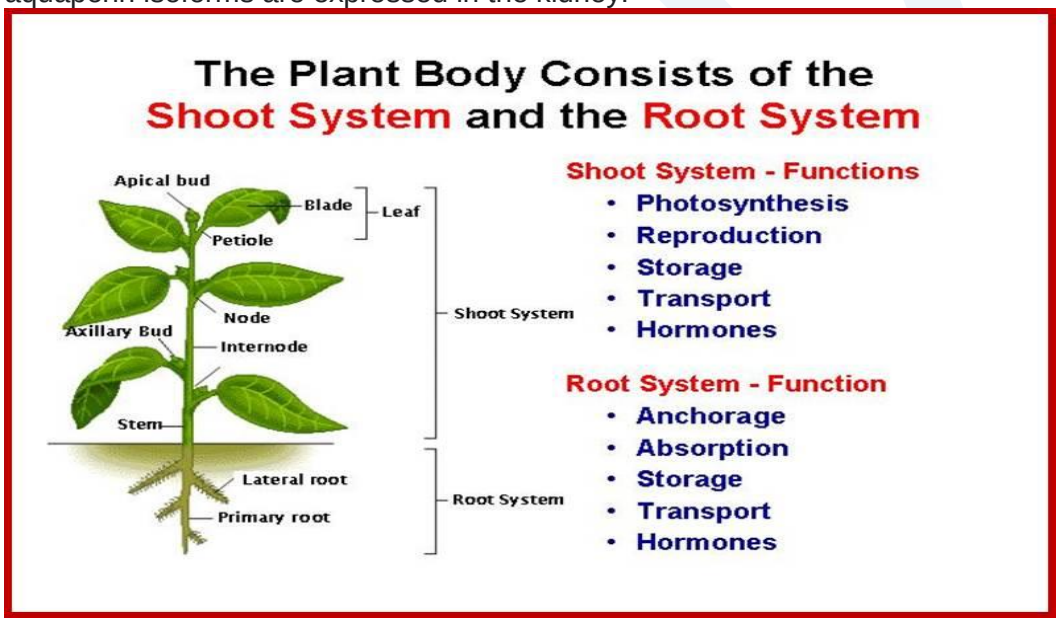
Transpiration is the biological process by which water is lost in the form of water vapour from the aerial parts of the plants." Transpiration is the process of water movement through a plant and its evaporation from aerial parts, such as leaves, stems and flowers. Water is

necessary for plants but only a small amount of water taken up by the roots is used for growth and metabolism. The remaining 97–99.5% is lost by transpiration and guttation.



6 Absorption of water

Water Follows the Osmotic Pressure Gradient Through Water Channels. **Water reabsorption is by osmosis through water channels in the membrane**. These water channels consist of a family of proteins called aquaporin. At least seven different aquaporin isoforms are expressed in the kidney.



7 Effect of growth substance:

At optimum temperature .The activity of auxins ,gibberellins and cytokinins (growth promoters) are high and activities of abscisic acid (growth regulator)is low with the result that plant growth rate is increased .At low and high temperature ,the balance of growth substances changes and affect growth .

8 Effect on development:

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

9 Effect on growth duration:

The heat unit or growing degree day (GDD) concept was developed to explain the relationship between growth duration and temperature. This concept assumes a direct and linear relationship between growth duration and temperature. The growth duration ultimately determine the dry matter production and yield of crop.

A degree day or heat unit is the summation of mean temperatures minus base temperature. The base temperature is the temperature specific to particular crops where growth is zero. The base temperature for rice maize is 10^{o}c and for wheat is 4.5^{o}c

$$GDD = \sum \left(\frac{T_{max} + T_{min}}{2} - T_b \right)$$

Where ,T_{min} = maximum temperature

T_{max} = minimum temperature

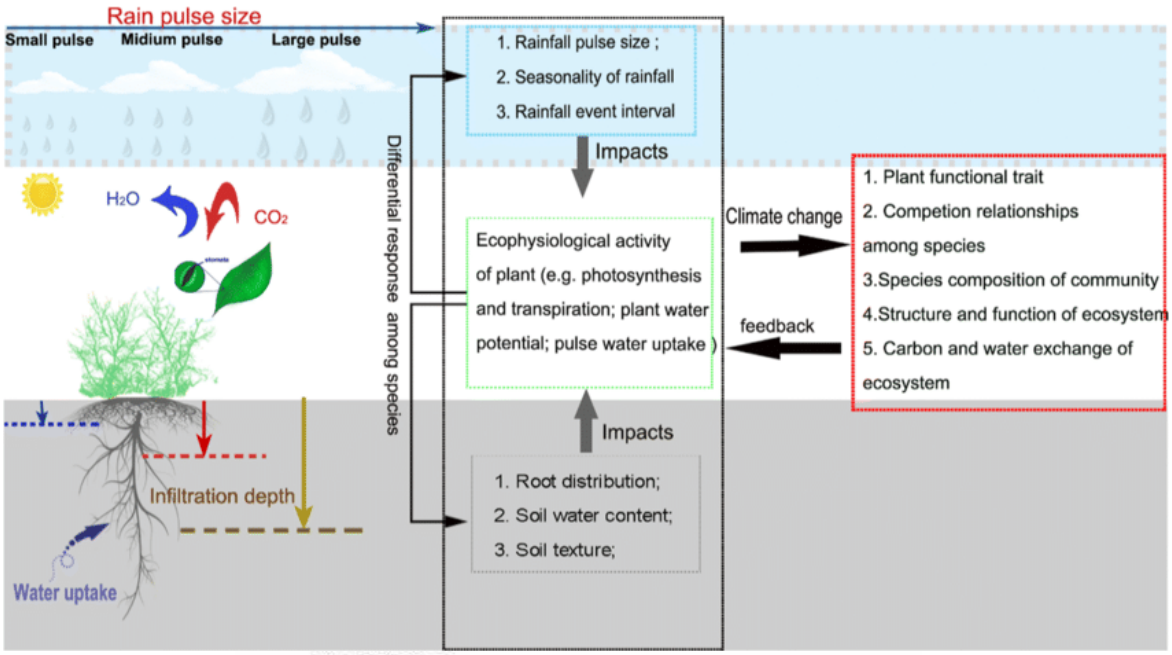
T_b = base temperature

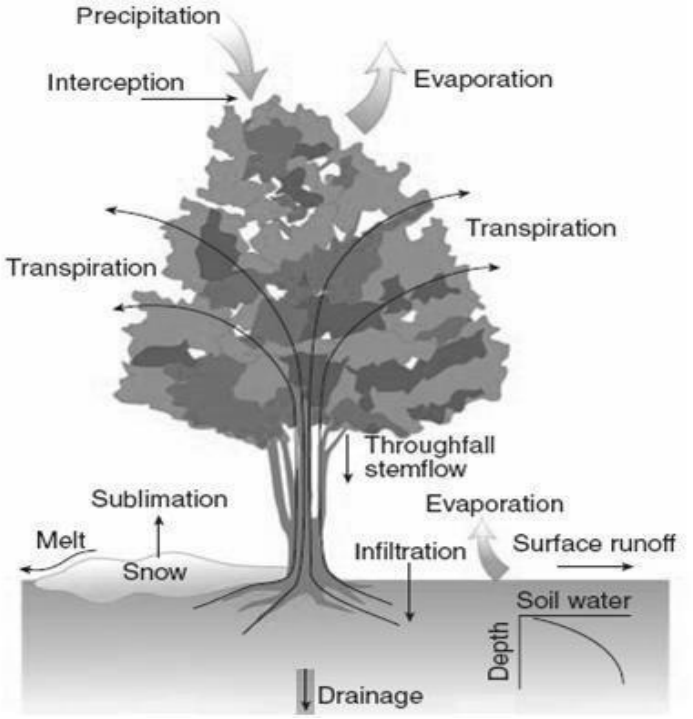
Most plants tolerate normal temperature fluctuations. In general, foliage plants grow best between 70 degrees and 80 degrees F. during the day and between 60 degrees to 68 degrees F.

Precipitation:

Precipitation is the deposition of atmospheric moisture to the ground .Precipitation occurs in forms such as rainfall, hail, snow, fog and dew. Rainfall greatly affects the distribution and cultivation of both cultivated and native plants .Total amount of rainfall and their distribution and intensity determine the crop production and crop productivity of the location .The amount of rainfall may be quite as required by the crops but it may useless if it is not distributed throughout the growing season of the crops . Thus distribution of rainfall during growing season is important .The quantity of rainfall per hour or per day (rainfall intensity) affect the utilization of rainfall Soil has capacity to absorb moisture at certain rate, the infiltration capacity of soil. If the rainfall is greater than the rate of absorption by soil, the surplus water will be lost as surface runoff .It will cause flooding and soil erosion.

Water is essential for maintaining turgidity of cell ,which is necessary for most of physiological functions of plants .Water is necessary for photosynthesis and transpiration .Transpiration regulates the temperature and facilitate in the gas exchange of plants .Water act as a solvent and medium for chemical reaction .It helps in the uptake of nutrients and translocation of photosynthesis in different parts of the plants .Water deficit at any growth stage can reduce the growth and yield of crops .There are certain stages of crops where water deficit can drastically reduce the yields .





Relative humidity:

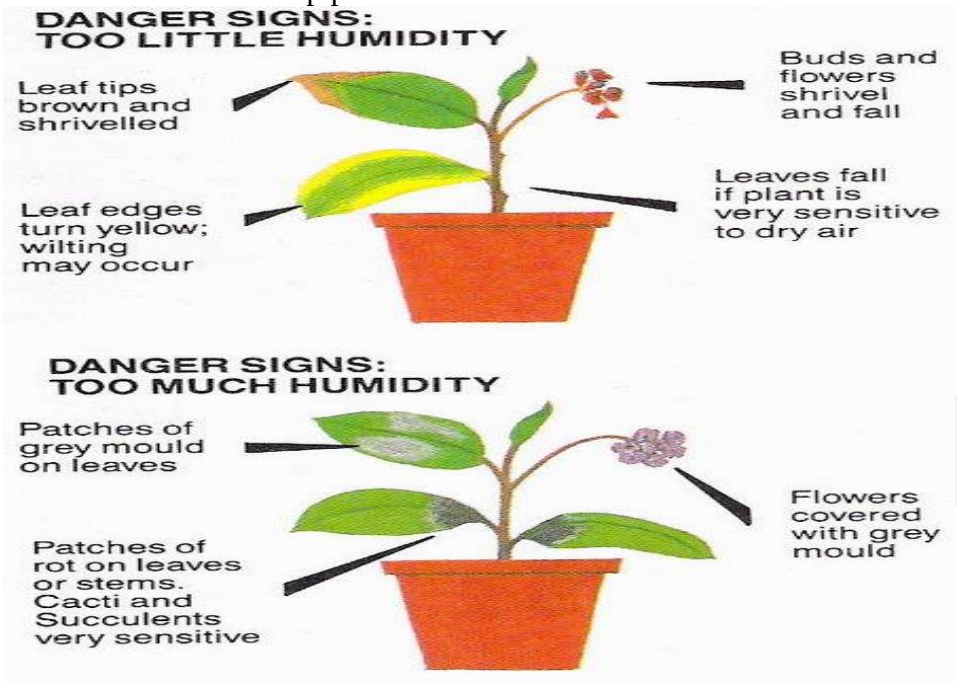
Humidity is the concentration of water vapour present in the air. Water vapor, the gaseous state of water, is generally invisible to the human eye.[2] Humidity indicates the likelihood for precipitation, dew, or fog to be present.

Three primary measurements of humidity are widely employed: absolute, relative, and specific.

1 **Absolute humidity** is expressed as either mass of water vapor per volume of moist air (in grams per cubic metre) or as mass of water vapor per mass of dry air (usually in grams per kilogram).

2 Relative humidity, often expressed as a percentage, indicates a present state of absolute humidity relative to a maximum humidity given the same temperature.
3 **Specific humidity** is the ratio of water vapor mass to total moist air parcel mass.

Humidity refers to the amount of water vapour in the air expressed as percentage of the maximum amount that the air is capable of holding at given temperature ,The rate of evapotranspiration is strongly related to relative humidity .Lower relative humidity may cause water deficit in plants where water is limiting factors .Higher relative humidity reduces the transpiration which may retard gas exchange in plants .The incidence of insect ,pest and diseases is high under light relative humidity .About 70-80% relative humidity is considered ideal for crop production .



What does a relative humidity of 80% mean?
For example, a warm and humid summer with 80% humidity at 86°F, would mean that **the outdoor air contained 0.8oz/m3 of water**. In our homes, 86°F would be very uncomfortable so many would use air conditioners to cool it down again
The ideal relative humidity for health and comfort is somewhere between **30-50%** humidity, according to the Mayo Clinic. This means that the air holds between 30-50% of the maximum amount of moisture it can contain.
So, what is the best humidity level for plants? An ideal humidity range for most mature plants is **50% to 60%**. Some tropical plants, such as pineapple, are accustomed to humidity levels up to 90%. Many succulents, such as cacti, will be fine with humidity levels as low as 10%.

5. Wind:
Wind velocity has direct and indirect impact on crop production. Wind direction and velocity have significant influence on crop growth. Wind increases the turbulence in atmosphere, thus increasing the supply of carbon dioxide to the plants resulting in greater photosynthesis rates. Wind alters the balance of hormones. Wind increases the ethylene production in barley and rice.
A) Carbon dioxide mixing/photosynthesis:

When air still, a thin layer of air (about 1 cm thickness) surround the leaf surface is called boundary layer resistance which becomes barrier in the exchange of gas in the leaf .When air is turbulent (2 m per second), there is no boundary layer resistance .Thus, moderate winds have beneficial effect on photosynthesis by continuously replacing the carbon dioxide absorbed by the leaf.

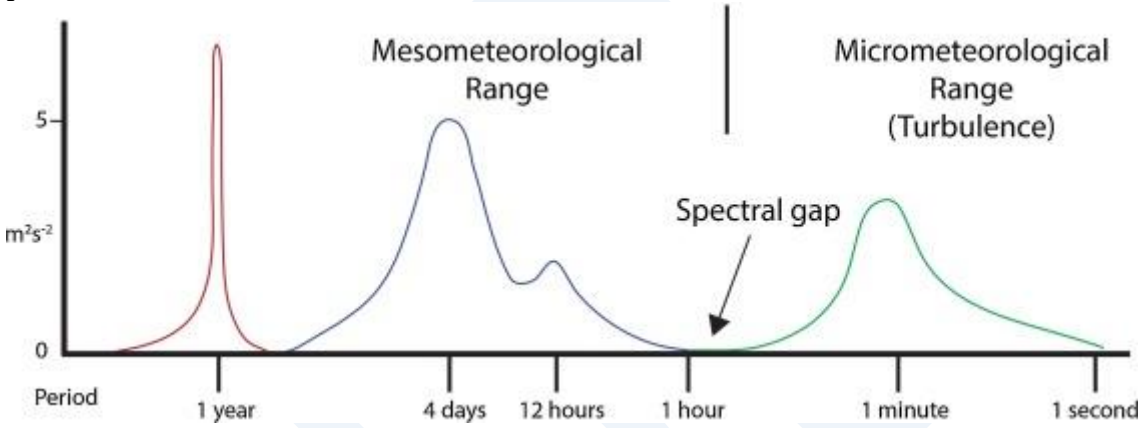
B) Mechanical damage:

Strong wind cause mechanical damage to the plants by wounding ,uprooting and lodging of the whole or parts of plants .Such plants will have higher respiration rate and lower growth .It also disturbs the hormonal balance.

C) Plant water relationship:

Strong the evapotranspiration and May close the stomata when wind is very strong .Strong wind can thus disturb relationship .Hence growth of plants is adversely affected.

Assignment 4(roll no 43-54) Explain the effect of temperature and solar radiation on crop productivity .How will you manipulate solar radiation and temperature in favor of crops production?



Climate change Impacts

1 Effect of rising temperature:

In temperate climate, increased temperature could increase insect population. Rising temperature may affect insect survival, development, geographic range and population size. It may affect insect physiology. Under such situation some insects take several years to complete life cycle (Cicadas, Arctic moths) and some insects develop quickly at certain temperature range based on degree days (cabbage maggot, onion maggot, European corn borer, Colorado potato beetle, aphids, diamond back moth). Therefore, crop damage increase. Migratory pests may migrate earlier. Natural enemy-host relationship may affect resulting into reduced parasitism. Rising temperature may change gender ratios of insects such as thrips.

2 Effect of Precipitation:

Rain drops physically dislodge the insects from their hosts such as leafhoppers, plant hoppers, thrips, cut worms etc. while others drown to death e.g. mealy bugs, pupae of fruit fly, Helicoverpa, Spodoptera, Etiella , rice stem borers etc. Flooding is used as a control measure for termites and stem borers too. Heavy rainfall causes pest epizootics by fungal pathogens (sugarcane pyrilla). It is anticipated that cutworm infestation will be more in future because they are sensitive to flooding and summer rainfall, which will increase in future.

3 Effect of rising CO2 level:

Carbon dioxide is a perfect example of a change that could have both positive and negative effects. Carbon dioxide is expected to have positive physiological effects through increased photosynthesis. The impact is higher on C3 crops such as wheat and rice than on C4 plants like maize and grasses. The direct effects of changes in CO2 concentration will be through changes in temperature, precipitation and radiation.

4 Effect on insecticide Use Efficiency:
Warmer temperature requires more number of insecticide applications (i.e., three, more than normal) for controlling corn 15 pests. Entomologists predict more generation of insects in warm climate that necessitates more number of insecticide applications. It will increase cost of protection and environmental pollution.

5 Effect on natural pest control:
Global warming is expected to make regional climates more varied and unpredictable which could affect relationship between insects and their natural enemies. In years of most variable rainfall, the caterpillars have significantly less number of parasitoids. This could be because the parasitoids use cues e.g. change in local climate to determine the best time for laying eggs.

6 Effect on Forest insect pests:
It is difficult to predict impacts of climate change on forest insect pests because of complexity of interactions between insects and trees. Population of green spruce aphid (Elatobium abietinum) will increase due to global warming. The spruce bark beetle (Dendroctonus micans) will increase due to warming because its predator Rhizophagus grandis is benefited by temperature rise. The Asian long horn beetle (Anoplophora glabripennis) population will increase in warmer coastal areas that attack street plantations.

Climate Change
Global warming and climate change are the great concern of today since they affect not only the living beings but also the whole ecosystem of this world.

Causes of climate change
1 Natural Causes
a) Volcanic eruption
b) Global warming
c) Earthquake
d) Ocean current
e) Variation in solar radiation
f) Earth orbital change
g) Natural digester
2 Human Causes
a) Deforestation
b) Industrialization
c) Population growth
d) Excessive use of chemical
e) Greenhouse gasses

Following measurres can be adopted to reduce the impact of climate change:
1. Reduce methane leaks: Methane is a green house gas that contribute to the progress of climate change. Natural gas and petroleum system are also considered among the main

sources of methane emmision. Upgrading the equipment used in transferring, storing and producing oil and gas can limit methane leaks.

2. Divest for fossil fuels: Use of fossil fuels should be controlled. The CO gas from fossil fuels causes global warming and results climate change. So use of fossil fuels should be minimized.

3. Making environment green: Environment should be made green by planting trees. The green environment reduces carbondioxide and helps to reduce climate change. Green environment also reduce pollution and reduces global warming which results to reduce in impact of climate change.

4. Wind power: Wind power is the fastest growing energy resources in the world since 1990. Wind turbine use the wind, a renewable source of energy to generate electricity. It is eco- friendly and reduces impact of climate change.

5. Controlling industrialization: Industrialization and urbanization should be controlled. The chemicals produced and harmful gases from industrialization causes climate change. Pollution due to urbanization also causes climate change.

6. Reuse and Recycle: Recycling of paper, plastic, glass, aluminium, carboards etc. should be done to reduce impact of climate change.

7. Reducing uses of fuels: Fuel emissions associated with motor vehicles should be controlled . The fuels produce smoke also causes climate change . Its use should be reduce.

8. Controlling overpopulation and deforestation: Overpopulation and deforestation are the main causes for change in climate. Population should be controlled and plantation should be done for reducing impact of climate change.

9. Minimize green house gases: Emmisions of green house gases should be checked from different factories and industries. Green house gases are main cause for change in climate.

10. Use of renewable resources: Renewable resources should be used to generate energy. Renewable resources such as solar energy, hydroelectricity does not causes pollution than non- renewable resources. It makes environment clean, healthier and fresh . Hence helps to reduce climate change.

Monsoon

A **monsoon**is traditionally a seasonal reversing wind accompanied by corresponding changes in precipitation, but is now used to describe seasonal changes in atmospheric circulation and precipitation associated with annual latitudinal oscillation of the Intertropical Convergence Zone between its limits to the north and south of the equator. Usually, the term monsoon is used to refer to the rainy phase of a seasonally changing pattern, although technically there is also a dry phase. The term is also sometimes used to describe locally heavy but short-term rains.

The southwestern summer monsoons occur from July through September. The Thar Desert and adjoining areas of the northern and central Indian subcontinent heat up considerably during the hot summers. This causes a low pressure area over the northern

and central Indian subcontinent. To fill this void, the moisture-laden winds from the Indian Ocean rush into the subcontinent. These winds, rich in moisture, are drawn towards the Himalayas. The Himalayas act like a high wall, blocking the winds from passing into Central Asia, and forcing them to rise. As the clouds rise, their temperature drops, and precipitation occurs. Some areas of the subcontinent receive up to 10,000 mm (390 in) of rain annually.

Extreme difference is very much evident between wet and dry seasons in tropical seasonal forest. The image at left is taken at Bhawal National Park in central Bangladesh during dry season, and the right one is taken in wet Monsoon season. The southwest monsoon is generally expected to begin around the beginning of June and fade away by the end of September. The moisture-laden winds on reaching the southernmost point of the Indian Peninsula, due to its topography, become divided into two parts: the *Arabian Sea Branch* and the *Bay of Bengal Branch.*

A monsoon is a seasonal change in the direction of the prevailing or strongest, winds of a region. Monsoon cause wet and dry seasons throughout much of the tropics. Monsoon are often associated with Indian Ocean. Monsoon always blow from cold to warm regions. There are two types of monsoon that determine the climate of Nepal. They are:
1.Summer Monsoon
2. Winter Monsoon

• Summer Monsoon
Summer monsoon rainfall variability from June to September over Nepal. Summer monsoon generally arrives in early June characterized by violent lightning and thunderstorms and lasts up to the sept. Sometimes 10% of the total annual precipitation can occur in a single day. Similarly 50% of total annual rainfall can also occur within the 10 days of summer. The wind that flows northwestward from the head of Bay of Bengal transports moisture to the region of Nepal. The influence of summer circulation pattern is unequally distributed over the Himalayan of Nepal with greater rainfall in the central eastern part and less in wettest in the eastern part of Nepal like Dhankuta , Taplejung etc.

• Winter Monsoon
The Himalayas act as a barrier to the cold winds blowing from central Asia in the winter and forms the northern boundary of the monsoon wind patterns which lasts from October to April. Winter monsoon is due to the frontal system which generates more concentrated rainfall in the western part of Nepal and very few in the eastern part of Nepal. Winter Monsoon is less powerful than summer monsoon in Nepal it is because the Himalaya Mountain prevent much of the wind and moisture of the monsoon from reaching the coast. Winter Monsoon are sometimes associated with droughts. The rainfall can provide up to (1/5) of the annual total rainfall. Similarly, heavy rainfall in December and November is rare. Average temperature and rainfall during the peak summer and winter in three most popular tourist's area

The monsoon season in Nepal generally begins on June 13 and ends on September 23. Last year it started on June 11.

Generally, seasons around the world are divided into four; Spring, Summer, Fall and Winter.

Nepal boasts six seasons
1 Basanta (Spring)
2 Grishma (Early Summer)
3 **Barkha (Summer Monsoon)**
4 Sharad (Early Autumn)
5 Hemanta (Late Autumn)
6 Shishir (Winter).

Importance of Monsoon in Nepal Importance of summer monsoon
• Agricultural Importance
Agriculture for example relies on yearly rain. Many areas in our country do not have large irrigations systems, surroundings lakes, rivers are snowmelt areas. Aquifers or suppliers of underground water are shallow. The summer monsoons fills the wells and aquifers for the rest of the year. Rice and tea crops that relay o the summer monsoon. Dairy farms which help Nepal to supply large amount of milk also depend on the monsoon rains to keep healthy and well fed.
• Industrial importance
Some of the industry in Nepal and southeast asia also relies on the summer monsoon. A great deal of electricity in the region of Nepal is produced by hydroelectricity power plants which are driven by water collected during the monsoons. Electricity powers hospitals, schools and businesses that help to flourish the economic condition of Nepal.
• Reduces the import of goods from foreign country
When the summer monsoon is late or weak, the regions economy suffers. Fewer people can grow their own food and large agribusiness do not have produce to sell. So, the would be compilation to import goods from foreign country. Importance of winter monsoon Precipitation during the winter season has great importance in agriculture, particularly for the Rabi crops. Wheat among them is one of the most important crops which helps to meet Nepal food security problem. In some parts of Nepal there is some dryness after summer monsoon which is wet by rain of winter monsoon. So in that type of place winter rain helps to flourish the agriculture

3 Crop growth & Yield

Definition Crop Growth
Crop is defined as an "Aggregation of individual plant species grown in a unit area for economic purpose". Growth is defined as an "Irreversible increase in size and volume and is the consequence of differentiation and distribution occurring in the plant".

Five Development stage (Pheno-stage
1) Germination to emergence
Germination is considered complete when the radical (which becomes the primary root) ruptures the coleorhiza (root sheath) and emerges from the **seed**. The germination process begins when water is absorbed (imbibed) by the seed. This initiates several biochemical events necessary for seedling development. For example, enzymes secreted from the aleurone layer, break down starch in the endosperm converting it to simple sugars which nourish the embryo. All structural components of the grass seedling arise from the embryo.

The endosperm provides a quick source of energy for the developmental process, whereas the cotyledon (rich in fats and oils) provides energy for later stages of development.

2) Emergence to floral initiation

Floral initiation includes all of the developments necessary for the irreversible commitment by the meristem to produce an inflorescence. Control of floral initiation is not restricted to the developing meristem, but may involve signals from other areas of the plant.

3) Floral initiation to anthesis

Floral initiation of most temperate fruit crops occurs in late summer or autumn, between nine and twelve months prior to flowering. Exceptions include the female flowers of pecan and kiwifruit in which floral initiation and differentiation occur in spring and coincide with budburst approximately two months prior to bloom. There is general agreement that floral initiation is inhibited by gibberellins and promoted by cytokinins.

4) Anthesis to physiological maturity

After floret fertilization, cellular division is rapid, during which the endosperm cells and amyloplasts are formed. This period is known as the lag phase and lasts for about 20 to 30 percent of the grain filling period. After there is a phase of cell growth, and differentiation and starch deposition in the endosperm, which corresponds to linear grain growth and takes from 50 to 70 percent of the grain filling period.

5) Physiological maturity to cession of growth

Physiological maturity (maximum accumulation of dry matter) was reached at 30 days after anthesis

Growth Phase

1 Lag growth phase

It is the slower phase where cell division is slow.

2 Logarithmic growth phase

Here, the growth is very fast and known as the exponential phase too. A steep curve is formed.

3 Decreasing growth phase

Grow constant stable.

4 Seady growth phase

Here, the growth is steady or stationary and becomes constant.

Growth Response Curve

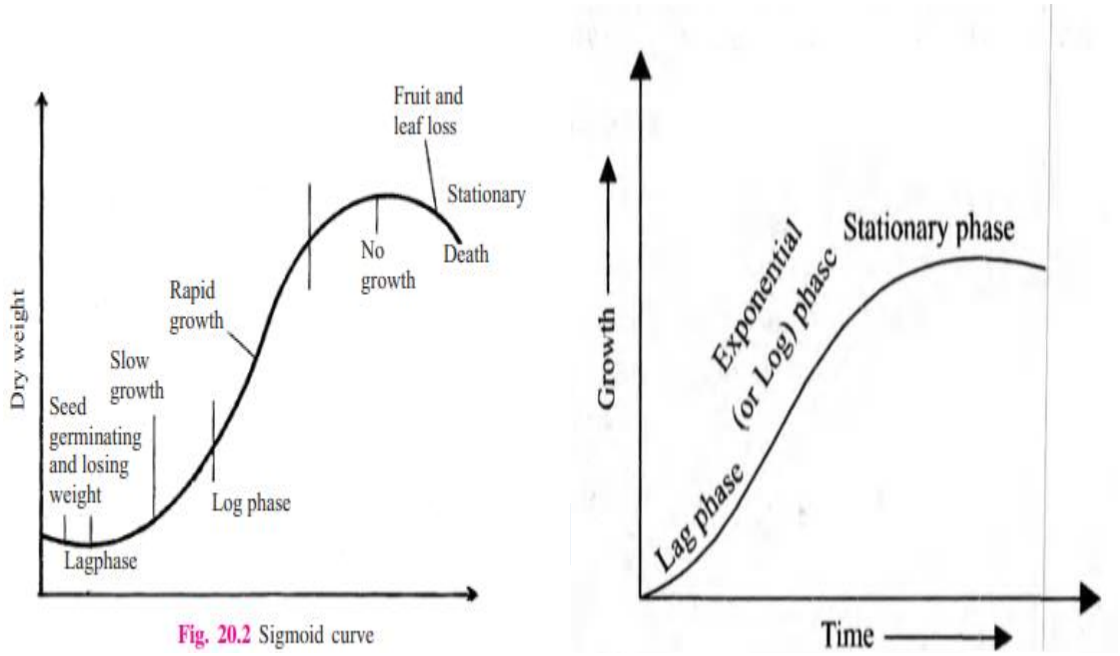


Fig. 20.2 Sigmoid curve

I want that during any crop period starting from day 1, to nth number of day till the cropping season ends, this sigmoid curve should retain this shape, whatever the crop duration is. The end day - is variable here, which may be 90, 100, 120, 150, etc. depending upon the crop type)

Characteristics of plants growth

Some of the characteristics of plant growth are mentioned below:

1 Plant Growth is Indeterminate:

Plants have meristems which are present in roots and shoots both. Meristems provide a proper response for primary growth. Due to the presence of meristems only, the plants grow indefinitely throughout their life. Meristems have the capability to divide and self-propagate. This is because plant growth is said to be indeterminate.

2 Plant Growth is Measurable:

Growth simply indicates a regular increment in protoplasm. Growth in plants is measured by the increment of cell number, area, volume, length, etc. Usually, the growth in plants is hard to measure, this is why the increment in the quantity of plant growth is measured accordingly using protoplasm increment. The increment of plant growth and protoplasm shares a proportionality.

1 Sprout

Each seed contains a small parcel of nutrients that is all they need to germinate and begin growing their first pair of leaves.

2 Seedling

As plants' roots develop and spread, a boost of quickly absorbed, **well-balanced nutrients** fuels the rapid growth from spindly seedling to healthy plant.

3 Vegetative

Nitrogen is a key component of chlorophyll, the green pigment in plants, so it's the **critical nutrient** when their energy is focused on growing stalks and foliage.

4 Budding

Phosphorus is in extra high demand at the start of a plant's reproductive cycle, the transition from growing leaves to forming buds.

5 Flowering

Potassium plays a primary role in producing and transporting the sugars and starches plants use up as they **develop healthy flowers and fruit**.

6 Ripening

When flowers and fruit are verging on full maturity, they need a week or two of just water without nutrients, a process known as "flushing," so they can use up all the nutrients they have already absorbed.

Measuring crop growth

Growth is, measured by a variety of parameters such as (i) Increase in length, e.g., stem, root, pollen tube, (ii) Increase in volume e.g., fruits, (iii) Increase in area, e.g., leaves, (iv) Increase in diameter, e.g., tree trunks, fruits, (v) Increase in fresh or dry weight.

1 Weighting plants- Fresh vs Dry weight
2 Root mass- Fresh vs Dry weight
3 Root shoot ratio both length & weight
4 Recording number of day from plants sowing to emergence of first cotyledon

- Calculate germination
- Measure height of plant
- Leaf count
- Leaf area index
- Number of branches

Factor Affecting of crop Growth

They are two type
1 External Factor
2 Genetic Factor

External Factor

1.1 Biotic Factor

Biotic factors impact crop production in the subsequent ways:
1. Earthworms improve the texture of the soil.
2. Microbes such as nitrogen-fixing bacteria increase the fertility of the soil.
3. Insects serve as predators and keep the number of crops under control.
4. Biotic factors like insects, rodents, pests, and many more spread the disease and reduce crop production. Biotic factors like insects, parasites, diseases, etc.

*** Animal *Birds * Human * Insect * Microbes * Earthworm**

1.2 Abiotic factors

Abiotic factors impact crop production in the subsequent ways:
1. Sunlight aids in photosynthesis.
2. Water and minerals from the soil along with gases are the raw materials for the synthesis of food and energy.
3. Suitable temperature is required for the proper growth of the plant and various processes such as transpiration.
4. Rainfall is required for natural irrigation of plant.
5.1 Abiotic factors like humidity, temperature, moisture, wind, rain, flood and many more destroy the crop raise. Abiotic factors like hot, cold, drought, salinity, etc. affect crop production. Resistant variety can withstand these factors and give a high yield.

* Topography * Edaphic factors * Climate factor * Soil microbes *Growth restricting

2 Genetic/ Internal Factor

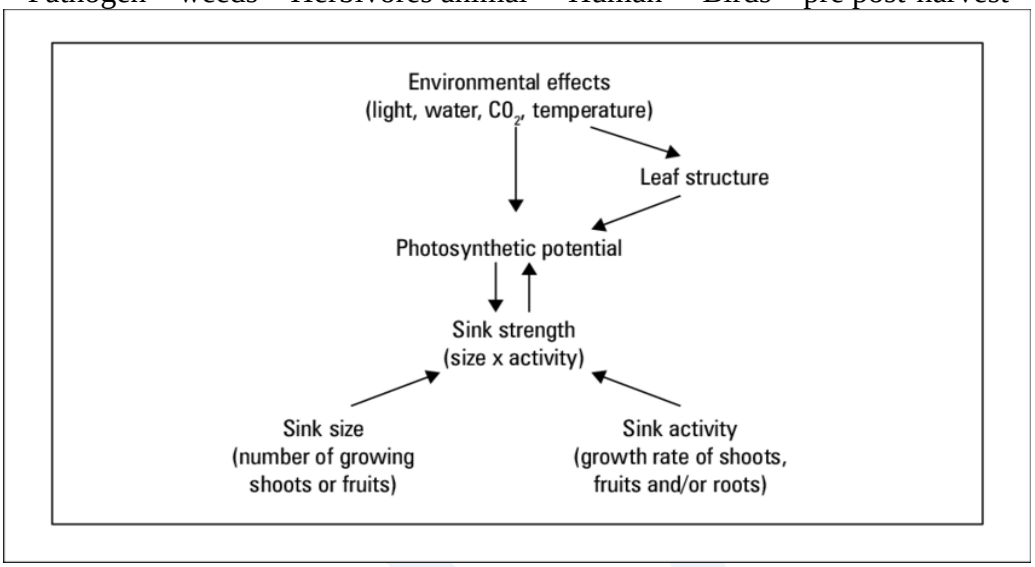
1. Genetics can be easily known with the development and introduction of new varieties & hybrid of cultivated crops and consequently upon there has been a big jump in the production & productivity of crops.
2. Variety & Plant nutrient needs: it is obvious that, the high crop yields produced with modern hybrid varieties, will require more plant nutrient than was necessary for lower yields of past. Under low- fertility conditions a new high – yielding variety cannot develop to its full yield potential.

3 Abiotic stress

* temperature stress *Water stress *Wind stress * Use of climate

4 Biotic stress

* Pathogen * weeds * Herbivores animal * Human * Birds *pre post-harvest



Or

1. Temperature: Temperature is measure of intensity of heat. Physicists consider that, the temperature of our universe ranges from a low – 273 0C to a high of several million degrees near the center of sun. The range of growth for most agricultural plants however, is usually much narrower; perhaps between 15 to 40 0C.

a) **Photosynthesis:** The effect of temperature on photosynthesis is complex and different for plants of various species as well as the carbon dioxide content of the atmosphere, the intensity of light and the duration of light of given intensity.

b) **Respiration:** it is also affected by change in temperature. At very high temperature the rate of respiration is initially great but is not maintained.

c) **Transpiration:** The loss of water in vapour form stomata of leaves is influenced by temperature.

d) **Water absorption**: Low soil temperature may adversely affect the growth of plants by its effect on the absorption of water. If the soil temperature is low, Yet excessive transpiration take place and the plant may be injured because of tissue dehydration.

e) **Mineral element absorption**: this may be caused by lower respiratory activity or reduced cell membrane permeability, both of which could affect uptake itself as well as the rate and extent of root permeability in the soil.

f) **Soil microbial activity:** The activity of nitro bacteria and most of the heterotrophic organisms increase with a rise in temperature. Soil PH may be related with temperature, which may in turn affect the plant growth. It has

g) **Composition of soil air:** Temperature may also alter the soil air.

2. Moisture: the growth of many plant is proportional to the amount of water present. The plant growth is restricted both at very low and very high levels of soil moisture.

3. **Solar energy:** Solar energy is a significant factor in plant growth and development. The quality, intensity and duration of light are all important. a. Photoperiodism: Even though light quality & intensity may be limited significance from the standpoint of field grown crops, duration of light period is important. The behavior of the plant in relation to day length is termed as photoperiodism.

4. **Composition of atmosphere**: Carbon is required for plant growth and apart from water, is the most abundant material with in plants and other living things. The major source of carbon for plant is carbon dioxide gas is the atmosphere.

5. Soil structure and composition of soil air: The structure of soil, particularly those containing appreciable quantities of silt and clay, has a good influence on both root and shoot growth of plants

6. **Soil reaction: it** may affect plant development by its influence on the availability of certain nutrients required for growth.

7. **Biotic Factors:** Many biotic factors can limit plant growth and cause hazard to farming operation and pose a potential threat of reduce crop yields.

8. **Nutrient elements**: About 5 to 10 % dry weight of plants is composed of the nutrient elements viz. nitrogen, phosphorus, calcium, magnesium, sulphur, boron, chlorine, copper , iron, magnese, molybdenum, zinc etc.

9. **Growth restricting substances**: Normal development of plants can be restricted or stopped completely by toxic substances.

10. **Toxic atmospheric substance**: The quality of the atmosphere surrounding above gases parts of plants may under certain conditions influence growth.

Crop Yield

In agriculture, the **yield** is a measurement of the amount of a crop grown, or product such as wool, meat or milk produced, per unit area of land. The **seed ratio** is another way of calculating yields.

Definition of Biological yield and economic yield

The total dry matter produced by a crop is known as biological yield.

A fraction of the biological yield which is useful for human is known as economic yield.

Yield Estimation of Field Crops
Yield estimation of various crops have been attempt with the use of yield components. Yield cost of Rice crop are as follows

01. RICE

What would be the yield of rice grains, if the average panicle density/m2 260, No. of field grains/panicle 136, Test weight 20g. Estimate the yield of rice?

Solution

Yield of rice (ton/ha) =(10,000 X No. of panicle/m2 X No. of grains/panicle X Test weight) ÷ (1000 X 1000 X 100 X 10).

= (10,000 X 260 X 136 X 20) ÷ (1000 X 1000 X 100 X 10).

= 7.072 ton/ha.

02. WHEAT

Yield Estimation of wheat grain and straw from following information

· Spacing 20cm X 3cm.

· No. of effective tills/plant.

· No. of grains/panicle 32.

· Test weight 40 g.

· Grain: straw 1:1.5

Solution

Spacing= 20 X 3 cm2 =0.2 X 0.03 m2= 0.006 m2

0.006 m2 place have 1 till

= 1 m2 place have (1 ÷ 0.006) till = 500 tills.

Yield of wheat grain= (10,000 X No. Effective tills/m2 X No. of grains/panicle X test weight) ÷ (1000 X 1000 X 100 X 10).

= (10,000 X 500 X 32 X 40) ÷ (1000 X 1000 X 100 X 10).

= 6.4 ton/ha.

Yield of wheat straw= (6.4 X 1.5) = 9.6 ton/ha. [Given that grain: straw= 1:1.5].

03. MAIZE

Yield Estimation of maize from following information

· Spacing 75cm X 30cm = 0.75 X 0.3 m2 =0.225 m2.

· No. of cobs-2.

· No. of grains row/cob-10.

· No. of seeds/grain row- 25.

· Test weight 200 g.

Solution

Yield of maize= (10,000 X cobs/plant X grains row/cob X No. of seeds/grain row X test weight) ÷ (1000 X 1000 X 100 X 10 X spacing/m2).

= (10,000 X 2 X 10 X 25 X 200 g) ÷ (1000 X 1000 X 100 X 10 X 0.225).

= 4.44 ton/ha.

04. SUGARCANE

Yield Estimation of sugarcane from following information

· No. of millable cane/clump 15.

· Spacing of clump 90 X 60 cm2= 0.54 m2.

· Weight of cane 600 g.

Solution

Yield of Sugarcane= (10,000 X No. of millable cane/clump X Weight of cane) ÷ (spacing/m2 X 1000 X 100 X 10)

= (10,000 X 600 X 15) ÷ (0.54 m2. X 1000 X 100 X 10).

= 166.66 ton/ha.

Harvest index

Harvest index (HI) is the ratio of grain to total shoot dry matter and is as a measure of reproductive efficiency. HI is determined by interactions between genotypes (G), environment (E), and crop management (M). Harvest index helps to measure the difference between the potential and actual yield. It is the ratio between grain yield and plant yield. For each crop, it acts as an efficiency indicator.

HI was calculated according to the following formula:

$$\textbf{Harvest index (\%)} = \frac{\textbf{Grain yield}}{\textbf{Biological yield}} \times 100.$$

Potential yield

Potential yield is the maximum yield possible given rainfall in the absence of any other constraints. Estimates of potential wheat yield are obtained using the French & Schultz potential yield model:

yield (tonnes/ha) = WUE * (Stored Soil Water + Growing Season Rainfall - Evaporation)

Where WUE is the abbreviation for Water Use Efficiency and Growing Season Rainfall is from April to October inclusive. Stored Soil Water at the start of the growing season is modelled for 10 different soil types. Users can choose WUE of 12 or 15 kg/ha/mm.
Growing season rainfall is composed of cumulative rainfall at the time the maps and users can choose from decile 3, 5 or 7 rainfall finish for the remainder of the growing season.

Evaporation is either 110 or 90 mm.
The potential yield model assumes that:

- crop emergence occurs in April or May,
- the timing of rainfall during the season does not negatively affect crop growth (there is no drying off), and

- there are no soil constraints that hinder root growth.
- For later sowing and emergence (for example in June) use evaporatation rate of 90 instead of 110 mm.

Potential Crops
Potential Crops also known by various names such as underutilized crops/ orphan crops, Neglected and Underutilized Species are those to which little attention has been paid or which receive low priority from agricultural researchers, plant breeders and policymakers.

Attainable yield
Attainable yield is the crop yield grown under optimal management practices (i.e., recommended plant density, non-limiting nutrient condition, effective control of biotic stresses, etc.) in farmers' fields.

Actual yield
The actual yield is the quantity of a product that is obtained from a chemical reaction. In contrast, the calculated or theoretical yield is the amount of product that could be obtained from a reaction if all of the reactant converted to product.

The difference between the attainable yield and the theoretical yield is an unpreventable loss, whereas the difference between the actual yield and the attainable yield is a preventable loss. One can usually determine attainable yield experimentally. We must grow the crop free of constraints (e.g., pests).

Theoretical yield

This is called the **theoretical yield**, the maximum amount of product that could be formed from the given amounts of reactants.

Percent yield
The **percent yield** is the ratio of the actual yield to the theoretical yield, expressed as a percentage
Percent Yield=Actual Yield/Theoretical Yield×100%

National average yield
The average annual yield is the sum of all income (interest, dividends, or other) that an investment generates, divided by the age of that investment.

Yield gap
The yield gap, defined as the difference between actual farm yield and the yield potential with good management that minimizes yield losses from biotic and abiotic stresses, is a key biophysical indicator of the available room for crop production increase with current land and water resources.

The yield gaps are mainly caused by
1 Biological
2 Socio-economic
3 Climate
4 Institutional/policy related factors.

How can yield gaps be reduced?

For closing yield gaps, we need to implement various location specific agricultural input and management strategies. Adequate application of nutrients alone can increase crop calorie production by almost 20% whereas improvement of soil quality alone with adequate fertilizer application can generate an additional 30%.

4 Soil Fertility Nutrient Management

Soil Fertility: Soil fertility is the ability of the soil to provide all essential plant nutrients in available forms and in a suitable balance.

Soil productivity: The capability of soil to produce specified crop yield under well-defined and specified systems of management of inputs and environmental conditions.

Soil fertility refers to the ability of soil to sustain agricultural plant growth, i.e. to provide plant habitat and result in sustained and consistent yields of high quality. A fertile soil has the following properties:

- The ability to supply essential plant nutrients and water in adequate amounts and proportions for plant growth and reproduction; and
- The absence of toxic substances which may inhibit plant growth.

The following properties contribute to soil fertility in most situations:

- Sufficient soil depth for adequate root growth and water retention;
- Good internal drainage, allowing sufficient aeration for optimal root growth (although some plants, such as rice, tolerate waterlogging);
- Topsoil or horizon O is with sufficient soil organic matter for healthy soil structure and soil moisture retention;
- Soil pH in the range 5.5 to 7.0 (suitable for most plants but some prefer or tolerate more acid or alkaline conditions);
- Adequate concentrations of essential plant nutrients in plant-available forms;
- Presence of a range of microorganisms that support plant growth.

Soil Fertility	**Soil Productivity**
1. It is the ability of soil to provide mineral nutrients in the available form and suitable balance to the crops. 2. It is an index of available nutrients to plants. 3. It is one of the factors of crop production. 4. It can be analyzed in the laboratory. 5. Soil fertility = f (nutrient status of the soil) 6. All fertile soil is not necessarily productive for example lack water or drought.	5. It is the capacity of soil to produce crops. Soil fertility, crop management, water and climate contributes towards soil productivity. 6. It is broader term used to indicate yields of crops. 7. It is the interaction of all of the factors. 8. It can be assessed in the field under particular climate. 9. Soil productivity = f (soil fertility + management + Climate) 6. All productive soil must be fertile soil.

Plant nutrient is the study of the chemical element and compound necessary for plant growth, plant metabolism and their external supply.

Sources of nutrients are:
1. Organic manures
2. Plant residues
3. Chemical fertilizer
-Ammonium fertilizer
-Nitrate and Ammonium fertilizers
-Amide fertilizers
- phosphatic fertilizer
- potassic fertilizers
4. Bio-fertilizres
5. Rain water
6. Soil amendments and other micro nutrients.

1. Essential plant nutrients:
Source of plant nutrients:

The different source of 16 essential nutrients and their forms in which they are absorbed from the soil by the plant is shown below:-

Element	**Absorbable form**	**Sources**
Carbon,	Co_2	Air
Hydrogen	H_2O	Water
Oxygen	CO_2, H_2O , O_2	Water, Air
Nitrogen	No_2^- ,No_3^-,NH_4^+	Atmosphere, O.M.
Phosperous	$H_2Po_4^{2-}$, HPO_4^-	Soil Mineral. O.M.
Potassium	K^+	Soil Mineral. O.M.
Calcium	Ca^{2+}	Soil Mineral, Lime stone
Magnessium	Mg^{2+}	Soil Mineral, Lime stone
Sulphur	So_4^2	O.M. Rain water
Chlorine	Cl^-	Rain water
Iron	Fe^{2+},Fe^{3+}	Soil Mineral.
Mananese	Mn^{2+}	Soil Mineral
Zinc	Zn^{2+}	Soil Mineral. O.M.
Copper	Cu^{2+}	Soil Mineral. O.M.
Boron	H_2Bo_3, $H\ Bo_3^-$,HBo_3^{2-}	O.M.
Molybdenum	MoO_4^{2+}	Soil Mineral. O.M.

Plant nutrition

Plant nutrition is the study of the chemical elements and compounds necessary for plant growth and reproduction, plant metabolism and their external supply. In its absence the plant is unable to complete a normal life cycle, or that the element is part of some essential plant constituent or metabolite. This is in accordance with Justus von Liebig's law of the minimum. The total essential plant nutrients include seventeen different elements: carbon, oxygen and hydrogen which are absorbed from the air, whereas other

nutrients including nitrogen are typically obtained from the soil (exceptions include some parasitic or carnivorous plants).

Plants must obtain the following mineral nutrients from their growing medium:

1 Basic/Non-essential nutrients (96% CHO)
1.1Carbon
1.2Hydrogen
1.3Oxygen

2 Essential Nutrient
2.1 Macronutrients (primary)
2.1.1 Nitrogen
2.1.2 Phosphorus
2.1.3 Potassium

2.2 Macronutrients (secondary and tertiary)
2.2.1Sulfur
2.2.2 Calcium
2.2.3Magnesium

3 Micro-nutrients
3.1Iron
3.2Molybdenum
3.3Boron
3.4Copper
3.5Manganese
3.6Sodium
3.7Zinc
3.8Nickel
3.9Chlorine
3.10Cobalt
3.11Silicon
3.12Vanadium
3.13Selenium

Mobility of Nutrients:
1 Mobility in Soil:
(a) Mobile nutrients – Such elements are highly soluble and are not adsorbed on clay complex e.g. – NO^{-3}, SO_4^{2-}, BO_3^{3-} , Mn^{2+}, CI
(b) Less Mobile – Such elements are also soluble but adsorbed on clay complex and thus their mobility is reduced e.g. NH_4^+, K^+, Ca^{2+}, Mg^{2+}, Cu^{2+}
(c) Immobile – It is highly reactive and get fixed in the soil e.g. $H_2PO_4^-$, HPO^{2-} , Zn^{2+}

2 **Mobility in Plants:**
A mobile nutrients moves to the growing points in case of deficiency. Deficiency symptoms, therefore, appear on the lower leaves.

(a) Highly Mobile – N, P & K
(b) Moderately mobile – Zn
(c) Less mobile – S, Fe, Cu, Mn, Mo & Cl
(d) Immobile – Ca & B.

Classification based on Chemical nature.

The nutrients can be classified into cations and anions, metals and non metals based on chemical nature.

- **Cations:** NH_4^+, K^+, Ca^{++}, Mg^{++} , Fe^{++}, Mn^{++}, Zn^{++}, Cu^{++}, Co^{++}, Ni^{++}
- **Anions:** NO_3^-, Cl^-, MoO_4^{--} , $H_2PO_4^-$, HPO_4^- , SO_4^-
- **Metals:** K, Ca, Mg, Fe, Mn, Zn, Cu, Co, Ni
- **Non- Metals:** N, P, S, B, Mo, and Cl.

Criteria of Essentiality of Nutrients

This concept was propounded by Arnon and Stout (1939) and they considered 16 elements essential for plant nutrition. For an element be regarded as an essential nutrient, it must satisfy the following criteria;

1. A deficiency of an essential nutrient element makes it impossible for the plant to complete the vegetative or reproductive stage of its life cycle.
2. The deficiency of an element is very specific to the element in question and deficiency can be corrected /prevented only by supplying that particular element.
3. The element must directly be involved in the nutrition and metabolism of the plant and have a direct influence on plant apart from its possible effects in correcting some micro-biological or chemical conditions of the soil or other culture medium.

Constraints of soil fertility and productivity

- Mineral Composition. The mineral composition of the soil helps to predict the ability of the soil to retain plant nutrients.
- Soil pH
- Soil Texture
- Organic Matter contain
- Adding Manures and Fertilizers contain
- Leguminous Crops
- Soil structure

Management of soil productivity

1 Crop rotation
2 Conservation tillage
3 Compost/FYM
4 Cultivation of legume crops
5 Green manure
6 Bio fertilizer
7 Cover crops
8 Contour farming

Table 1.1 : Differences between Fertiliser and Manure

S. No.	Fertiliser	Manure
1.	A fertiliser is an inorganic salt.	Manure is a natural substance obtained by the decomposition of cattle dung, human waste and plant residues.
2.	A fertiliser is prepared in factories.	Manure can be prepared in the fields.
3.	A fertiliser does not provide any humus to the soil.	Manure provides a lot of humus to the soil.
4.	Fertilisers are very rich in plant nutrients like nitrogen, phosphorus and potassium.	Manure is relatively less rich in plant nutrients.

Organic Matter:-

They are bulky products produced from the plant, animal and their parts .It is the means by which agricultural production increases by recycle, renew to provide nutrients necessary for plant growth.

The main source of organic matter are plant and animal .Plants sources include crop residues ,dead and decaying leaves ,twigs, roots etc which are available on
The soil surface .Animal source includes FM, Dung, urine and other excreta including dead bodies as well.

On elementary composition ,the organic matter consist of : carbon (56-60%),Hydrogen (34-36%), oxygen (4-5%) ,Nitrogen (5%) ,prosperous (0.2-0.4%) ,sulphur (0.4-0.6%) ,Boran (.1%) ,iron ,calcium, magnesium ,copper ,zinc in trace amount dead tissues .

Organic manures:

Organic manures are mainly the plant and animals waste .They are added to the soil in order to increase the soil fertility and productivity ,They supply more nutrients but in low concentration .They protect soil structure ,soil texture ,improve porosity and infiltration capacity of the soil .

Properties of organic manure:

i) They are bulky in nature and it is required in higher amount as compare to chemical fertilizers.
ii) They supply humus which protects the soil by forming cementing material.
iii) Organic colloids have high water and nutrient holding capacity.
iv) They supply many nutrients in low concentration.

Classification of organic manures:

Organic manures are broadly classified into two types .They is:-
i) Bulky manure and
ii) Concentrated organic manures.

i) Bulky manure:-

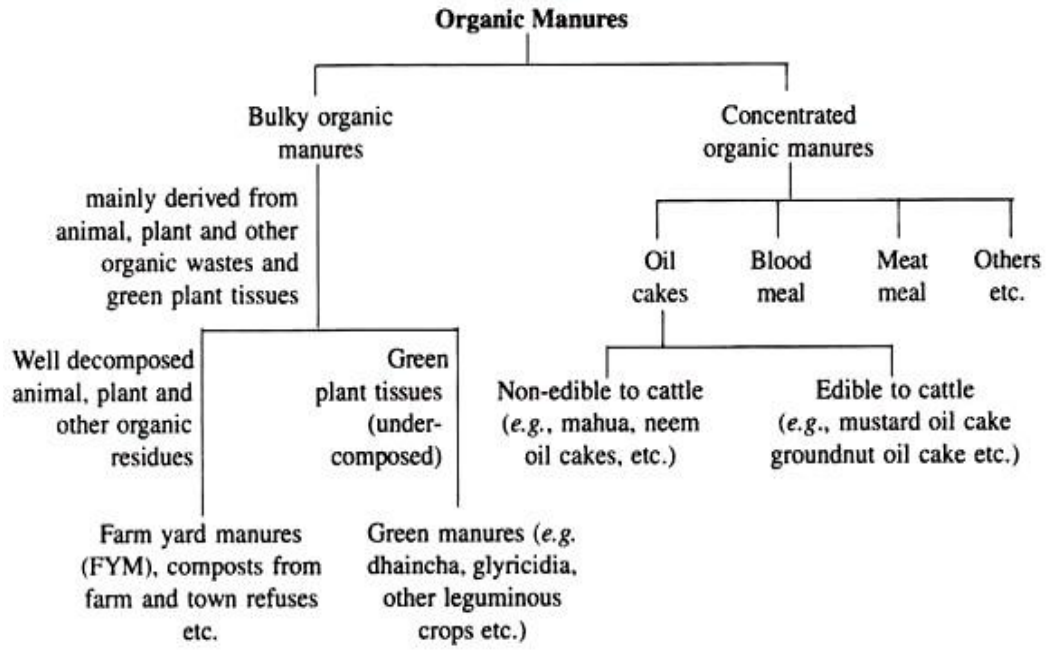
They contain low percentage or concentration of nutrients, they are applied in large quantities. FYM, and compost, green manure etc are examples of bulky manures.

i) FYM: - 0.5%N), 0.25% p, 0.5%K
ii) Compost: - 0.5%N), 0.15% p, 0.5%K
iii) Poultry manure: -1-1.8 %N), 1.4-1.8% p, 0.8-0.9%K
iv) Night soil: -1-1.6 %N), 0.8-1.2% p, 0.2-0.6%K

ii) Concentrated organic manure:

They contain higher amount of nutrient than bulky manures .Oil cakes ,blood meal , fish meal ,bone meal .The edible oil cakes are mostly used as concentrated feed for cattle and but their availability is very -very low .

Fish, bone and blood meal are commonly used as nutrient source in animal feed in smaller amount as manure.



FYM (Farm yard manure) and its preparation:-

1. FYM is the decomposed mixture of dung , urine and bedding materials of farm animals along with litter and left over materials from roughages or fodder fed to the cattle.
2. The amount of nutrients in FYM depends upon types of feed fed to animals. In many cases, urine is wasted from FYM due to faulty animal shed, which contain more nitrogen and potassium.
3. On an average FYM contain :

N (%) – 0. 5 - 1.5 , P2O5(%) - 0. 4 – 0.8 , K2O (%) – 0. 5 – 1.9

Preparation of FYM:-

FYM is prepared by two methods:
a) Without turning
b) With turning method

a) Without turning:-

- Dig a pit of (5 x 3 x 1 m^3) or convenient size near the livestock sed.

- Divide the pit into 2 equal parts and start filling first part of the pit daily with well mixed dung, bedding and urine until it is above 50 cm from the ground level .Cover the pit in a rounded manner with cow dung, mud, and slurry.
- Start filling the second part of the pit in the same manner like first.
- When second part of the pit is filling or after 3-4 months remove the rotten manure from the first pit which becomes ready for refilling.

b) With turning:-

- Prepare a pit of convenient size where dung, urine and bedding of four months can be adjusted.
- Divide the pit into 4 pits.
- Fill first in first month, second part in second month .After every one month turn or transfer the manure to another pit and after transferring 2 times (3 months) manure becomes ready for field use.
- After each pit above each pit above 50 cm cover it with dung mud slurry.

Compost and its preparation:

Compost is the microbial degradation of organic waste of almost all kinds covering it into fine black matter decomposition of organic matter requires warm moist and aerated environment.

A mass of rotted organic matter made from waste materials like crop residues, dung of cattle or any kinds of waste from plant or animal origin.

Nutrient content vary according to kinds of materials used for preparation.
N:P2O5: K2O (%)
Compost (rural) 0.4-0.8 : 0.3 – 0.6: 0.7- 1
Compost (Urban) 1- 2: 1:1.5

Method of preparing compost:-

1) Pit method:-

This method is adopted in all season except rainy season .It is common of composting in terai and inner belts turning at every 25 days internal procedure compost faster than that of without turning .

Steps involve on making pit method.

i) Dig a pit of convenient size depending upon the composting material.
ii) Fill the pit about 30cm depth without plant materials .The plant materials if dry, wet them so that it contain about 50 - 70% moistures.
iii) Prepare a starter and apply in a thin layer 93.5cm) at every 30 cm composting material.
iv) Repeat the step and until the pit is 50 cm above the soil surface.
v) Plaster the pit with dung mud slurry. f
vi) Compost becomes ready in 2-2.5 months by not turning but in 1.5 months the compost becomes ready by turning.

2) Heap method:

Composting of plant materials during monsoon season may be may be disturb by water logged condition in pit method so heap method is prepared .It is done by piling the plant Materials above the shouldn't be less than $1m^3$ and height of the heap shouldn't exceed 1m.

Steps involve in making heap method:

i) Pile the composting materials on the top of the wood or raised ground to ensure proper aeration and prevent logging.

ii) Apply starter materials (3-5cm thick) at every 30 cm composting materials.
iii) Repeat step to until the desired height is achieved.
iv) Plaster the heap with dung mud slurry or with a black plastic by inserting poles at different level.
v) After 15 days internal open the heap dismental and reseal it.
vi) The compost becomes ready after 2 months which depends upon the composting material

GREEN MANURING:-

Green manure are two type

1 Green manures In Situ:

Any crop(generally legumes) is grown in the field and incorporated in the soil in the same field to increase the fertility of soil is called Green manure in Situ. Example: Dhaincha, Sunhemp, Cowpea, Berseem etc.

2 Green leaf manure/ Ex Situ:

Gathering of green biomass (leaf and tender twigs) from bunds, nearby roads, forest or from some other places and incorporating these biomass in field to increase fertility status of soil. Example: Glyricidia, Leucaena, and Eupitorium etc.

It is system of making manure by collecting green leaves from the forest areas or growing trees on the boarder of the field of vacant places to provide green leaves and twigs which provides organic matter and nitrogen to the soil.

Annual legume crops such as Dhaicha,Ghanshi,(Seshania,aculeate),sunn hemp(srotolaria juncea), berseem (Trifolium ,alexandrium ,cowpea (vigna species) lentil ,black gram etc are green to maturity or when it is about to flower they are mixed the soil and allow it to decay .

- A fast growing crops, generally legumes grown to incorporate in soil in green stage to improve organic matter content and soil fertility.
- Legume crops can fix atmospheric N to the soil as well as upon decomposition add organic matter to the soil.
- Examples: Dhaincha, Sunhemp, Velvet bean, and cowpea.

Characters

- Grow quickly
- Large canopy
- More succulent materials
- Especially legume
- Deep rot system
- Tolerable to hard weather

N content of green manures and green leaf manures (dry Wt. basis)

Green manures/ Green leaf manure.	N Content (%)	N accumulation (kg ha^{-1})
Crotolaria juncea (sunhemp)/ GM	2.8 – 3.15	80-130
Sesbania aculeata (Dhaincha)/GM	2.55 – 3.21	130-185

Sesbania rostrata (Dhaincha)/GM	3.20 -3.37	170-220
Glyricidia sepium (glyricidia)GLM	2.25 -2.76	
Artemisia vulgaris (Titepati)GLM	2.40	
Eupatorium adenophorum (Banmara)/GLM	2.35	
Adhatoda vesica (Asuro)/GLM	0.85 – 1.50	
Leuceana leucocehala (ipil ipil)/GLM	2.09 – 4.3	
Eichhornia crassipes (water hyacinth)/Weed	2.75 – 3.28	
Parthenium hystorophorus (parthenium)/Weed	2.68	
Cassia tora (cassia)/Weed	1.60	

Bio gas slurry as manure:-

Due to increase demand of organic manure bio gas slurry is effectively utilized in the crop field . This is the byproduct of biogas plant. It contain higher amount of nitrogen than FYM. While storing bio gas proper protection from solar radiation is necessary.

An aerobic decomposition of dung and urine in the bio gas plant produces methane gas which is use for heating and lighting purposes .The waste product obtained from bio gas plant is well decomposed manure that can used directly in the field.

VERMICOMPOST

Compost prepared with the help of earthworm. The most common species of earth worm used are

1. Eisenia foetida
2. Eudrius eugeniae

Any kinds of crop residues, waste materials, and animal dung can be used to prepare.
Amount of nutrients vary according to materials used but contain higher than general compost. On an average it Contain:
N: P2 O5: K2O (%) = 3: 1: 1.5

Poultry Manure

- Manure obtained from the poultry industries.
- The decomposed product of excreta of poultry, and poultry litters.
- On an average it contain:

N: P2O5: K2O (%) = 3: 2. 5: 1.5

- The nitrogen content of the poultry manure is lost by 50% if it is kept exposed for several weeks.
- The use of poultry manure is increasing because of its availability.

Animal manures: The droppings from sheep and goat which on an average contain N: P2O5: K2O (%) 3:1:2 is used as good source of manure.

Night soil: it is excreta of the human, both solid and liquid. It contain N: P2O5:K2O (%) 5.5: 4 : 2

Sewage and sludge: This is also human excreta in solid from is called sludge and liquid portion is called sewage water. This is also used as manure after decomposition.

Oil seed cake

After oil is extracted from oilseeds, the remaining solid portion is dried as cake which can be used as manure. The oil cakes are of two types:

- **Edible oil cake**: which can be fed safely to cattle. Example: Coconut, rapeseed , Cotton, Groundnut and linseed cake
- **Non edible oil cake** which are not fit for feeding livestock. Example: Castor, Neem, Mahua, Karanj cake.

Average Nutrient Contents (%) of Oil cakes

Oil cake	N	P_2O_5	K_2O
Castor cake	4.3	1.8	1.3
Mahua cake	2.5	0.8	1.2
Karanj cake	3.9	0.9	1.2
Rape seed cake	5.2	1.8	1.2
Coconut cake	3.0	1.9	1.8
Groundnut cake	7.3	1.5	1.3
Cotton seed cake	3.0	1.9	1.8
Sesamum cake	6.2	2.0	1.2

Importance of Manure

- These are a good source of macronutrients.
- Improves soil fertility
- Maintain soil fertility
- Cost-effective
- Reduces soil erosion and leaching.
- Improves the physical properties of the soil and aerates the soil.
- Improves the nutrient holding capacity of the soil.
- Improves the water holding capacity of the soil.
- It can be transported easily.
- Methane gas is evolved as the by-product of manure that can be used for cooking and heating purposes.
- The crops grown on the land treated with manure produces healthy crops.
- Increase soil carbon
- Increase water retention
- Green manure help the weed control
- Water erosion control
- Microbes activates high

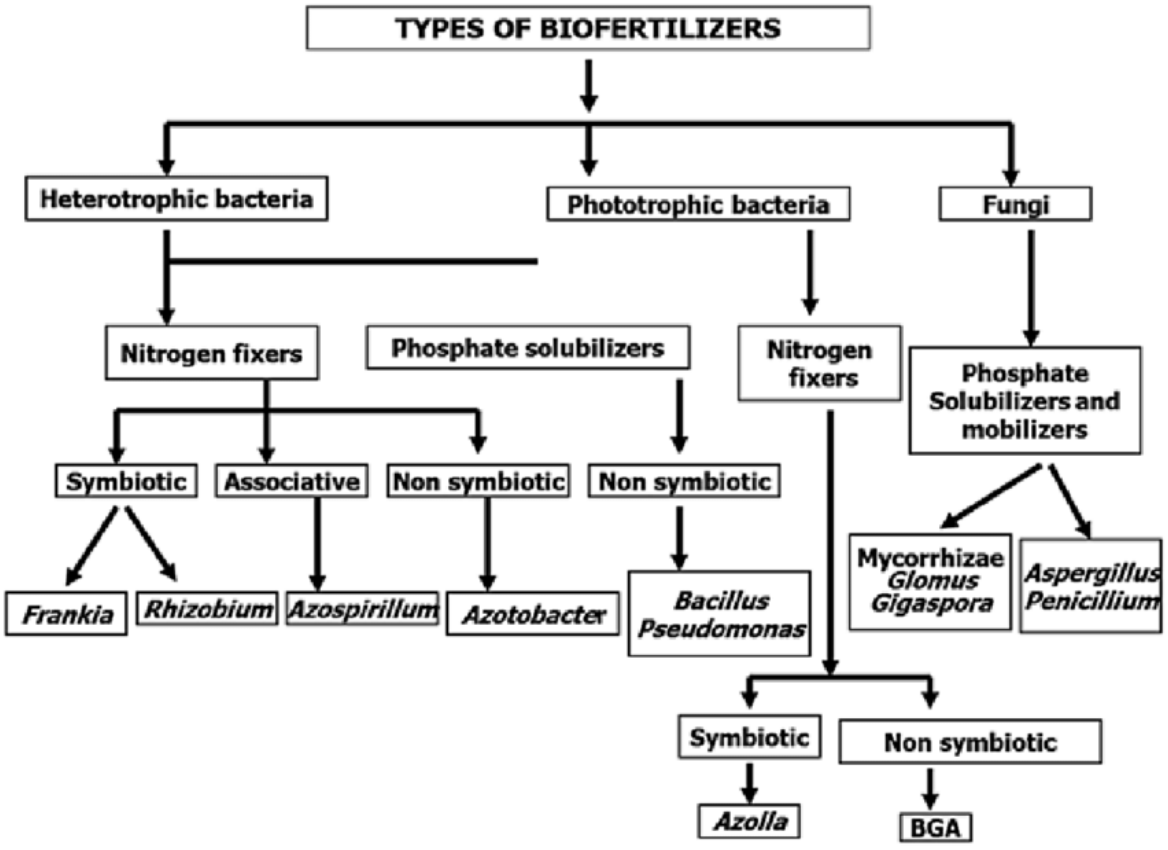
Bio fertilizer:-

Biofertilizer is a substance which contain living micro-organisms which, when applied to seeds, plant surfaces or soil, colonize the rhizosphere or interior of plant and promotes growth by the supply or availability of primary nutrients to host plant.

Biofertilizers add nutrients through nitrogen fixation, solubilizing phosphorus and potassium, and stimulating plants growth through synthesis of growth promoting substances.

Nitrogen is the very important source of nutrient for the plant .Atmospheric air contain 78% Nitrogen which isn't utilized by majority of the plants and animals .Some micro organisms have got the ability to trap the Nitrogen gas and convert it into nitrogenous compounds .In addition to this different group of algae, Azolla plant harbor nitrogen fixing bacteria and also their bio mass is converted into manure .Thus the use of living organisms as manure is termed as bio fertilizer.

- Live cell are used as bio fertilizer
- Are renewable source of nutrient
- Supplement chemical fertilizer
- Stabilized C:N (20:1) ratio of soil
- Soluble, mobilize nutrient though natural process



Classification of bio fertilizers

1. **Symbiotic nitrogen fixer:** Example: Rhizobium bacteria (Legumes) , Azolla (Anabaena azollae).
2. **Non symbiotic nitrogen fixing organisms:** Example: Azotobacter(Free living soil bacteria), Azospirillum (Bacteria), Blue green algae(BGA),
3. **Phosphorus solubilizing biofertilizers:** Example: Pseudomonas and Bacillus(bacteria), Penicillium and Aspergillus (Fungi), Mycorrhizae and Vasicular Arbuscular Mycorrhiza (Symbiotic association between soil fungi and plant roots)
4. **Fast decomposing organism:** Example: Example: Cellulolytic fungi (Aspergillus, penicellium and trichoderma), lignolytic organism,Fungi (Agaricus, ployporus)
5. **Potassium solubilizing bacteria:** Example: Acidithiobacillus ferrooxidans, paenibacillus spp., Bacillus mucilaginosus, B. edaphicus, B. circulans have ability to solublize K minerals like biotite,muscovite, feldspar, mica, iolite and orthoclase.

K- Solubilizing Bacteria

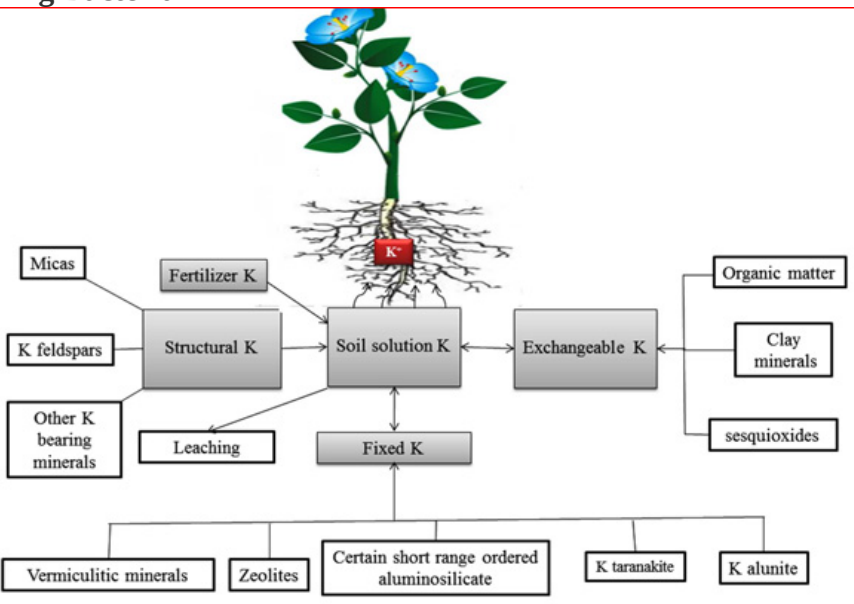


Figure 1. Interrelationships of various forms of soil K (Sparks and Huang, 1985).

(A) N2 Fixing Bio-fertilizers

- ***Free-living :*** *Beijerinckia, Azotobacter, Anabaena, Nostoc,*
- ***Symbiotic :*** *Rhizobium, Frankia, Anabaena azollae*
- ***Associative Symbiotic :*** *Azospirillum*

(B) Phosphorus Solubilizing Bio-fertilizers

- ***Bacteria (PSB) :*** *Bacillus megaterium, Bacillus subtilis, Bacillus circulans, Pseudomonas striata*
- ***Fungi (PSF) :*** *Penicilliumspp, Aspergillus awamori*

(C) Phosphorus Mobilizing Bio-fertilizers

- ***Arbuscularmycorrhiza :*** *Glomus spp., Gigaspora spp., Acaulospora spp.*
- ***Ectomycorrhiza :*** *Laccaria spp., Pisolithus sp., Boletus sp., Amanita spp.*
- ***Ericoid mycorrhizae :*** *Pezizellaericae*
- ***Orchid mycorrhiza :*** *Rhizoctonia solani*

(D) Bio-fertilizers for Micro nutrients

- ***Silicate and Zinc solubilizers :*** *Bacillus spp.*

(E) Plant Growth Promoting Rhizobacteria (PGPR)

- ***Pseudomonas :*** *Pseudomonas fluorescens*

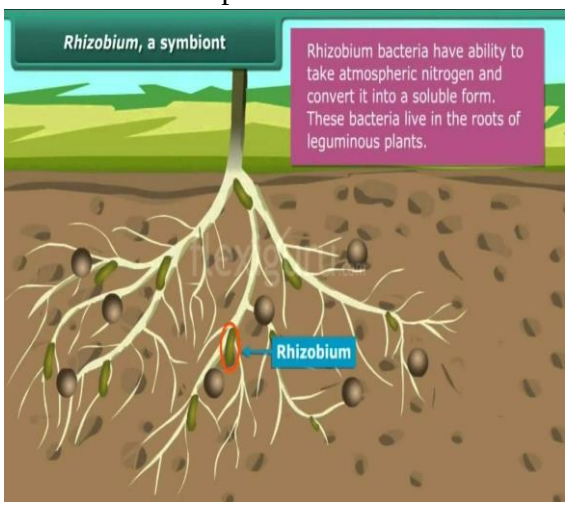
FAST DECOMPOSER

- Microorganisms that are capable of decomposing organic matter at faster rate.
- Cellulolytic fungi (Aspergillus, penicellium and trichoderma), lignolytic organism,Fungi (Agaricus, ployporus)
- Natural process of decomposition is accelerated and time is reduced by 4-6 weeks
- Many products are available in the market like EM, Waste decomposer etc

RHIZOBIUM

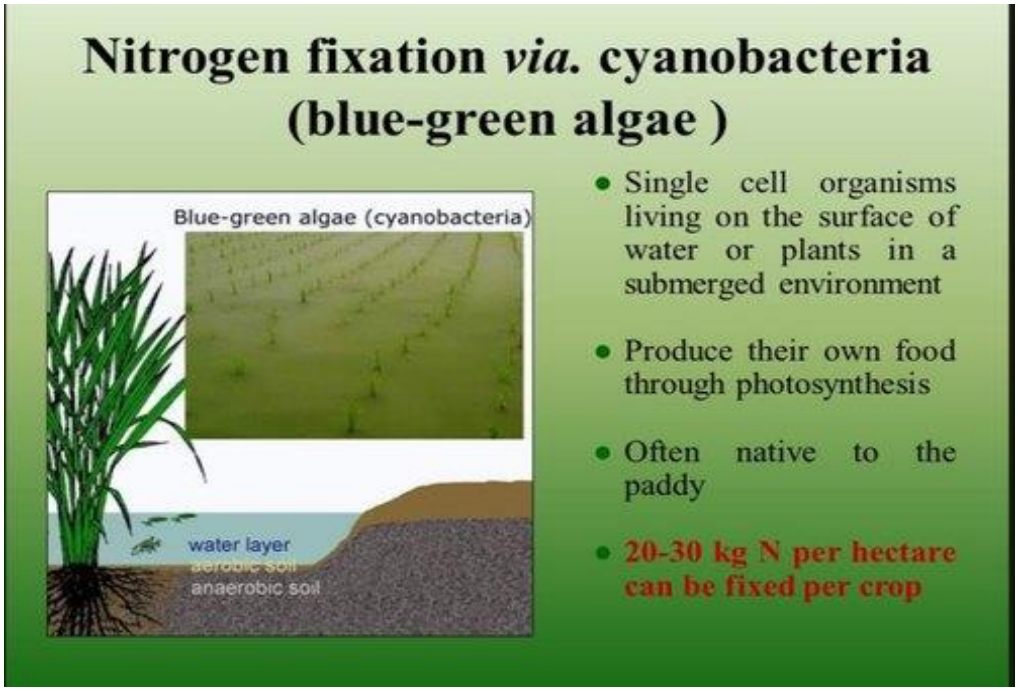
Rhizobium bacteria is symbiotically associated with legume crops and fix atmospheric nitrogen ranging from 47-220 kg/ha. The residual effect on succeeding crops may be 20-25 kg N/ha

- Different species of legumes have different species of Rhizobium
- Different products are available in the market.



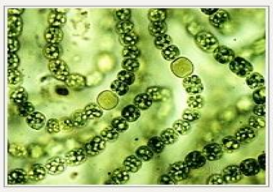
Blue-Green Algae (BGA)

- Can fix atmospheric N in the range of 15 -45 kg N/ha
- Temp range for better growth 25-45^0 C
- PH- 7-8
- Bright sunshine
- 2cm standing water
- Most important species
- Anabaena and Nostock



AZOLLA

- Azolla is a free floating fresh water fern. Azolla pinnata is the most common species occurring in Nepal.
- It fixes nitrogen due to Anabaena species of BGA present in the lobes of azolla leaves.
- A thick mat of azolla supplies 30- 40 kg N/ha.
- It is also used as animal feed and also as composting materials.

Characteristics	Nostoc	Anabena
Image		
Domain	Prokarya	Prokarya
Kingdom	Bacteria	Bacteria
Phylum	Cynobacteria	Cynobacteria
Order	Nostocales	Nostocales
Family	Nostocaceae	Nostocaceae
Genus	Nostoc	Anabeana
Description	Forms a gelatinous colony – cells appear cylindrical, spherical or ovoid	Filaments (trichomes) may be coiled or straights, solitary or clustered

Economic Value

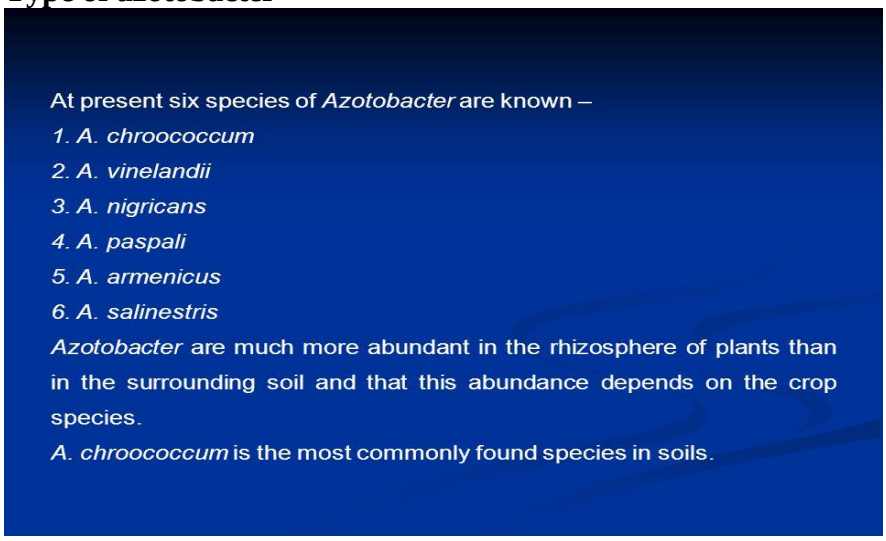
On dry weight basis Azolla contains the following chemical compositions:

- Nitrogen : 5.0 %
- Phosphorous : 0.5 %
- Potassium : 2.0-4.5 %
- Calcium : 0.1-1.0 %
- Magnesium : 0.65 %
- Manganese : 0.16 %
- Iron : 0.26 %
- Crude Fat : 3.0-3.3 %
- Sugar : 3.4-3.5 %
- Starch : 6.5 %
- Chlorophyll : 0.34-0.55 %
- Ash : 10.0 %

AZOTOBACTER

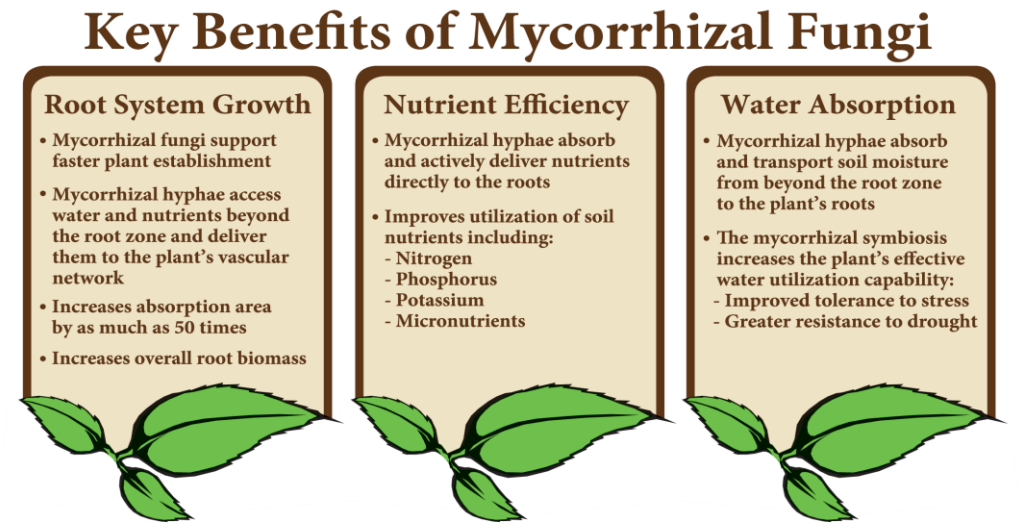
- A free living bacteria found in soil, water, and rhizosphere.
- Can fix atmospheric nitrogen to the soil in the range of 20 -30 kg N/ha
- The Inoculum of bacteria is available in the market for the use in the soil.

Type of azotobacter



MYCORRHIZA

- The term " Mycorrhiza" is made up from two words Mycor(fungus) and rhiza(root) and literally means root fungus.
- There is symbiotic relationship between green plant and fungus. Plants provides sugar produced in the process of photosynthesis whereas fungus provides water and nutrients especially phosphorus to the plants**.**



Importance of Biofertilizers

Biofertilizers are important for the following reasons:

- Biofertilizers improve the soil texture and yield of plants.
- They do not allow pathogens to flourish.
- They are eco-friendly and cost-effective.
- Biofertilizers protect the environment from pollutants since they are natural fertilizers.
- They destroy many harmful substances present in the soil that can cause plant diseases.
- Biofertilizers are proved to be effective even under semi-arid conditions.

Application of bio fertilizers

- **Seed treatment :**

In the slurry of inoculants, the seeds are uniformly mixed, and then they are dried under the shade for 30 minutes. Within 24 hours, the dried seeds should be sown. Ten kilograms of seeds can be treated with one packet of the inoculant (200 g).

- **Seedling root dip :**

Transplanted crops are grown using this method. In 40 litres of water, two packets of the inoculant are mixed. The roots of the seedlings are dipped in the mixture for 5 to 10 minutes and then transplanted.

- **Foliar application :**

A liquid bio fertilizer can be applied by fertigation or foliar application to a crop. Alternatively, it can be applied through seed treatment or root dipping.

- **Main field application :**

A mixture of four packets of the inoculant and 20 kg of dried and powdered farmyard manure is broadcast in the main field just before transplanting.

- **Set treatment :**

Sugarcane sets, potato pieces, and banana suckers are usually treated with this method. Culture suspension is made by mixing 1 kg (5 packets) of bio fertilizer in 40-50 litres of water and keeping cut pieces of planting material in the suspension for 30 minutes. Before planting, the cut pieces are dried in the shade for some time. A ratio of approximately 1:50 of bio fertilizer to water is used in set treatment.

- **Better water relation and drought tolerance :**

The mycorrhizal fungi play an important role in the water economy of plants. Their presence increases the hydraulic conductivity of the root at lower soil water potentials, and this is a factor in the better uptake of water by plants.

Fertilizers:
A fertilizer is any material of natural or synthetic origin that is applied to soils or to plant tissues to supply one or more plant nutrients essential to the growth of plants.

Classification of chemical fertilizer :

Fertilizers are classified into three types on the basis of nutrient supply and nutrient contain.

A. According to number of nutrients contained

1. Single/simple/straight fertilizer: Fertilizers that supply only one nutrient. On the basis of the nutrient, they may be of the following types:

a. Nitrogenous fertilizer

i. Fertilizer containing nitrogen in ammonium (NH_4) form such as ammonium sulphate, ammonium chloride etc.

ii. Fertilizer containing nitrogen in nitrate (NO_3) form such as calcium nitrate, sodium nitrate, potassium nitrate etc.

iii. Fertilizer containing nitrogen in amide form such as urea.

b. Phosphatic fertilize

i. Fertilizers containing water soluble phosphorus such as super-phosphate, concentrated superphosphate, etc.

ii. Fertilizers containing citrate soluble phosphate such as dicalcium phosphate, basic slag etc.

iii. Fertilizers containing insoluble phosphate such as rock phosphate.

c. Potassic fertilizer

Such as potassium chloride, potassium sulphate etc.

2. Compound fertilizer: Fertilizers containing more than one nutrient through chemical bonding. Such as monoammonium phosphate (MAP), (diammonium phosphate (DAP) etc.

3. Mixed Fertilizer: Fertilizers prepared through mixing of different fertilizers. They may be of the following two types:

a. Complete fertilizer: Mixed fertilizer that contains 3 primary nutrients i.e. N, P and K.

b. Incomplete fertilizer: Mixed fertilizer that contains any 2 primary nutrients i.e. N and P or, K and P or, N and K. The quantity of nutrients varies in different fertilizer mixtures, based on which they may be classified as:

i. Low grade fertilizer mixtures: This category of mixture contains a total of plant nutrients up to or less than 14 per cent in it. Such mixtures are termed as low grade mixtures.

ii. Medium grade mixtures: This category of mixture contains a total of plant nutrients between 15 to 24 per cent in it.

iii. High grade mixtures: When the total nutrient contents range between 25 to 35 per cent in any mixture then the mixture is said to be of high grade.

Fertilizer mixtures can be prepared at the farm or at home. **The following combinations should be avoided in preparing the mixed fertilizers at home:**

• Ammonium sulphate, ammonium chloride, other ammoniacal fertilizers and nitrogenous organic manures with lime.

• Sodium nitrate or potassium nitrate with superphosphate.
• Nitrochalk with superphosphate or lime.
• Ammonium Sulphate-nitrate with lime.
• Urea with superphosphate.
• Superphosphate with lime or calcium carbonate or wood ashes.

B) On the basis of nutrient supply :

It is divided into 3 types:

a**) Straight fertilizers:**

Those fertilizers that supply single nutrient e.g. Urea, MOP, SSP, DSP,TSP etc. .

b) Complex fertilizer:

Those fertilizers that supply 2 plant nutrients in different proportion at the same time e.g: DAP -18% N ,46% p.

c) Complete fertilizer:

Those fertilizers that supply all three nutrient (NPK) in equal proportion e.g; Nitrosophosphate with potash (15:15:15 % NPK) Neutromin (19:19:19%NPK)

C. Fertilizers can also be classified based on physical form

1. Solid-

Powder (single superphosphate)
• Crystals (Ammonium sulphate)
• Prills (Urea, Diammonium phosphate, superphosphate)
• Granules (Holland granules) • Supergranules (Urea supergranules)
• Briquettes (Urea briquettes)

2. Liquid fertilizers-

Usually a concentrated form to be mixed with water.

D. BASED ON CONCENTRATION NUTRIENTS

1 LOW ANALYSIS FERTILISERS

• Fertilisers contain less than 25% of primary nutrients.
• Example- ⎪ SSP(16% P_2O_5) ⎪ Sodium nitrate (16% N)

2 HIGH ANALYSIS FERTILISERS

• Total content of primary nutrients is above 25%.
• Example- ⎪ Urea (46% N) ⎪ Anhydrous ammonia (82.2% N) ⎪Ammonium phosphate (20% N +20% P_2O_5)

Inorganic nitrogen fertilizers:

i) Urea ($Co(NH_2)_2$) - 46% N
ii) Ammonium nitrate :- (NH_4 ,No_3) - 33 %N
iii) Diammomium Phosphate - $(NH_4)_4$ - 18%N,26P iv)Sodium nitrate - ($Na(No_3)_2$) - 16% N
v) Calcium nitrate - ($Ca(No_3)_2$) -15 %N
vi) Potassium nitrate - (KNO_3) - 13 % N
vii) Ammonium sulphate - $(NH_4)_2So$) -21%N
viii) Ammonium phosphate - $(NH_4)_2Po_4$)- 20%N

Organic nitrogen fertilizer:-

FYM, Compost, Vermi compost, Oil cakes like cotton cake (6:3:2%NPK)

All organic nitrogen fertilizers (manures) release nitrogen slowly, buildup soil structure.

Chemical fertilizers urea, Ammonium sulphate ,DAP are commonly available nitrogen containing fertilizers. NH,NO,No ions are absorbed by the plant through their roots .Nitrogen fertilizers are mobile and soluble in water .The loss of nitrogen by leaching, denitrification and volatilization is a major problem .Use of nitrogen fertilizer must be done correctly and in split dose .Band placement at 5-6 cm below the soil surface minimize ammonium volatilization. De-nitrification takes place is warm and extremely wet soil.

Composition behavior and use of phosphate fertilizer:-

1) Single super phosphate – 16% phosphorus
2) Double super phosphate -32 % phosphorus
3) Triple super phosphate – 48% phosphorus
4) Diammonoum phosphate -46% phosphorus
5) Rock phosphate 20-40% phosphorus
6) Bone meal (organic source -25-28% phosphorus

1) Single super phosphate – 16% phosphorus
2) Double super phosphate -32 % phosphorus
3) Triple super phosphate – 48% phosphorus
4) Diammonoum phosphate -46% phosphorus

These four fertilizer are most popular in Nepal.

SSP, DSP, TSP and DAP are more popularity used in all types of soil .The availability of DAP is more in the Nepalese market.

To make phosphorous maximum available, the PH of the soil should be maintained at .6.5 PH. In acid soil below 6.5 PH, Prosperous combines with Iron or aluminum (Fe^{2+}, $fe3^{+}$ Al^{3+}) to form relatively insoluble compound .Similarly in alkaline PH phosphorus combine with calcium to form calcium phosphate.

As compare to Nitrogen, Phosphorus is less mobile .Phosphorus can be broad casted or can practice band placement or line placement phosphorus is applied at the time of final land preparation.

COMPOSITION BEHAVIOR AND USE OF POTASSIC FERTILIZER:-

i) Murate of potash – 60% k_20
ii) Potassium sulphate – 50%
iii) Potassium nitrate -21%
iv) Potassium phosphate – 41 -54 %

Murate of potash is popular in Nepal .Potassium fertilizer are less mobile than nitrates leaching occurs in sandy soils under heavy rainfall condition, Potassium is generally applied as basal dose by broadcasting or line sowing. In long season crops to ensure optimum utilization and prevent losses split application of potash fertilizer is often done. The amount of fertilizer (K^{+}) present in the organic matter leach out very quickly .Since it is available in ionic farm.

Chemical Fertilizers and their characteristics

NITROGEN FERTILIZERS

Nearly all chemical N fertilizers contain either ammonium (NH4+) or nitrate (NO3-) nitrogen. The nitrate form is quicker acting because it's more immediately mobile (leachable) and reaches the roots sooner if applied to a growing crop. But, remember gets converted quickly to mobile nitrate in warm soils (all of it within 7-10 days).

Common Nitrogen Fertilizers

1. Ammonium Nitrate (33-34% N):

Contains half nitrate N and half ammonium N, so is quicker acting than straight ammonium fertilizers; Absorbs moisture and becomes slushy in high humidity; should be kept in well

sealed bag; it can become explosive if mixed with oil and releases oxygen when exposed to fire, which encourages combustion.

2. Ammonium Nitrate with Lime (26% N):

It is coated with dolomitic limestone to neutralize the acid-forming properties of regular ammonium nitrate and to reduce moisture absorption.

3. Ammonium Sulfate (20-21% N):

It contains 23% sulfur (or 69% sulfate) along with N.

4. Urea (45-46% N):

The highest-strength solid form of N. Its N is initially in the amide form (NH2) but is converted to ammonium in moist warm soils within 1-2 days (a week or two in cooler soils) and then to nitrate by soil bacteria. Urea is mobile and leachable until its amide N has been converted to ammonium. Regardless of soil pH, some N will be lost to the atmosphere as ammonia gas if urea is left on the soil surface. Losses are highest above a soil pH of 7.0 and can reach 35% when urea is broadcast (spread) over grass pastures. Losses are minimal, however, if rainfall or irrigation occur within a few hours after such surface applications. It can "burn" (injure) seeds and seedlings if placed too close due to release of free ammonia. It absorbs moisture, but not as much as ammonium nitrate. It can be fed to ruminants like cattle as a protein source the rumen bacteria convert the N to protein;

5. Sodium Nitrate (16% N):

Its nitrate N is readily leachable. Unlike most ammonium N fertilizers, it has a gradual basic effect on the soil. It can easily burn seeds and seedlings because of its very high salt content. It absorbs moisture and can become slushy in high humidity, so storage bags should be well sealed.

PHOSPHORUS FERTILIZERS

The phosphorus in most chemical fertilizers comes from reacting rock phosphate with sulfuric, phosphoric, or nitric acids or with anhydrous ammonia. A chemical fertilizer's Phosphorous can exist in several forms which should be listed on the label: Water-soluble Phosphorous: This type of Phosphorous is soluble in water and moves quickly out of the granules into the soil. When P fertilizer is broadcast on soils below pH 7.0, water solubility isn't important, because soil acidity helps dissolve the P.

Common Phosphorus Fertilizers

1. Single Superphosphate (16-22% P_2O_5, 8-12% S):

A common Phosphorous fertilizer and also a good sulfur source. About 78% of its Phosphorous is water soluble (see above). Are made from rock phosphate and sulfuric acid.

2. Triple or Concentrated Superphosphate (42-48% P_2O_5):

Has much more Phosphorous than single super but only 1-3% sulfur. About 84% of its Phosphorous is water soluble. Made from rock phosphate and phosphoric acid.

3. Ammonium Phosphate Fertilizers:

There are 3 classes, all with 100% water-soluble Phosphorous viz. i) Mono-ammonium phosphate (11-48-0, 12-61-0) which works better than all-ammonium phosphate on alkaline soils; is low in sulfur and less likely to cause burning than DAP ii) Di-ammonium phosphate (16-48-0, 18-46-0, 21-53-0): A good Phosphorous source but can injure seeds or seedlings due to ammonia release if placed too close iii) Ammonium Phosphate sulfate (16-20-0, 13- 39-0): Both are also good sources of sulfur (91% S in 16-20-0, 7% S in 13-39-0) iv) Miscellaneous NP and NPK Fertilizers: 20-20-0, 14-14-14, 12-24-12, etc.

POTASSIUM FERTILIZERS

The most common Potassic fertilizers are:

1. Potassium chloride (Murate of Potash):
Contains about 60%-62% K2O
2. Potassium sulfate:
Contains about 48-50% K2O and 18% S.
3. Potassium nitrate (13-0-44).
4. NPK fertilizers like 10-20-10, etc. NOTE: Tobacco, potatoes, and sweet potatoes are sensitive to high amounts of chlorides which affect crop quality. In this case, potassium chloride should be avoided or minimized.

SECONDARY NUTRIENT FERTILIZERS (Calcium, Magnesium, Sulfur)

Calcium and Magnesium:

Even acid soils have enough calcium for most crops. Where liming is needed and magnesium is also deficient, dolomitic limestone (a mixture of calcium and magnesium carbonates) should be used. Liming with calcium only can also provoke a Mg deficiency. Gypsum has no effect on soil pH and is often used to supply calcium to crops with high needs, such as peanuts, without increasing the pH. Magnesium sulfate (epsom salts; 9-11% Mg) and Potassium magnesium sulfate (11% Mg) are other sources and have no effect on soil pH. The Mg content of fertilizers is often expressed in terms of magnesium oxide (MgO);

Sulfur:

Some common fertilizers are good S sources like single superphosphate (8-12% S), ammonium sulfate (23-24% S), 16-20-0 (9-15% S), and potassium sulfate (17% S). Usually, the higher the NPK content of the fertilizer, the lower the S content (i.e. triple superphosphate contains only 1-3% S). Sulfur deficiencies are on the increase in nonindustrial areas, due to the growing use of high-analysis fertilizers with lower S contents.

Method of fertilizer application

Fertilizer applied are different methods mainly the three propose,
1To make nutrient easily available to the crops
2To reduce fertilizer losses
3For the ease of the application. Suitable methods particular situation depend on the nutrient of crops, soil and fertilizer materials. The following are the common methods of fertilizer application.

1) Solid forms of fertilizer

A) Broadcasting

Manures and fertilizers are broadcast by hands or machines uniformly on the soil. Well decomposed FYM, compost, oil cakes, bone meals, urea, superphosphate, lime are applied by this method. The plants can not utilized manures and fertilizers efficiency by this method.

B) Placement application

i) Plough sole placement:

Manure and fertilizers are paced in the plough sole after opening the furrow by the plough. Such furrows are covered immediately during the next run of the plough. This method is popular in dry soils where there is moisture only in plough sole layer.

ii) Deep placement:

This method is adopted in wetland rice field, where nitrogenous fertilizer (ammonium sulphate) is placed deep in the reduced layer to avoid denitrification loss.

iii) Sub soil placement:

It is followed in strongly acidic soils where P and K fertilizers are placed in deeper layers by heavy machinery to avoid fixation.

C**) Localized placement**

i) Contact placement: The small quantities of well decomposed manures, ashes and phosphatic and potassic fertilizers are placed along with seeds during sowing. Seed cum fertilizer drill is used for such placement.

ii) Band placement: In this method both manures and fertilizers are placed in bands on one sides of the row at about 5 cm away from the seed or plant in any direction. There are two types of band placement.

a) Hill placement: This method is applied in wide spaced crops like cotton, castor, cucurbits where manure and fertilizers are placed on both side of the plants only along or across the row but not along the entire row.

b) Row placement: The wide spaced row crops like sugarcane potato, maize, tobacco etc the manure and fertilizers are placed on one or both sides of the row in continuous bands.

iii) Pocket placement: In dry lands and in wide spaced crops like cotton, castor, cassava, cucurbits, chillies etc manures and fertilizers are placed deeper in to the pocket and seeds are sown in the same pocket about 5 cm above the fertilizer and manure or their mixture.

iv) Side dressing: In this method manures and fertilizers are applied along the side of a row or around a plant.

v) Pellet application: The nitrogenous fertilizers are pelleted in various types of mud bolls and placed deep into the soft saturated soils of wet land rice to increase nitrogen use efficiency (NUE). 2) Liquid forms of fertilizer. The liquid forms of manures and fertilizers solutions are applied to the soil by using the following methods.

i) Starter solutions: The fertilizer solutions in low concentrations are used for soaking seeds, dipping roots after uprooting or spraying on the seedlings to strengthen the seeds or seedlings for early rooting, establishment and growth.

ii) Foliar application: The fertilizer solutions (nitrogenous and mineral fertilizers) in low concentrations are sprayed to the foliage of the standing crop in the form of spray. The general principle is that the applied nutrients are absorbed by the plant leaves through their natural opening.

iii) Direct application to the soil: Liquid fertilizers such as anhydrous ammonia are applied directly to the soil with special injecting equipment. Liquid manure such as urine, sewage water and shed washing are let in the field.

iv) Application through irrigation water: The water soluble fertilizers are dissolved and diluted with irrigation water and applied either through surface, sub surface or overhead irrigation. Liquid and slurry manures are also diluted with irrigation water and supplied through surface irrigation.

Soil fertility problems in Nepal:

Nepalese agriculture suffers from soil fertility problem is due to the following reason.

1) Rapid population growth (2.3% annually) compels (force) people to deforestation, cultivation on marginal and sloppy lands and steeply slopes.

2) Soil loss by soil erosion mainly in hills, mid hills and high hills of Nepal is severe i.e. according to HMG/NK, 1970; 240 million m^3 of soil is lost annually from 147181sq.km area which is equal to 1.63 mm thickness of the top soil.
3) Increase of cropping intensity i.e. a single plot of land is used 3- 6 times yearly to grow crops.
4) Nepal has strongly acidic soil having coarse textural acid farming parent materials and high rain fall selectively remove bases from the soil.
5) Traditional farming system uses maximum FYM and compost .The Nitrogen content of Nepalese soil is very low. Unavailability of fertilizer is major problem in Nepal .At the same time the excessive use of chemical fertilizers detoriated the certain part of the terai soil.
6) The system of Green manuring retaining crop residues in the field application of fertilizer on the basis of soil test ,crop rotation ,soil conservation et. Hasn't played a dominant role in Nepalese agriculture.

There are five key factors that influence fertilizer application

- Granule uniformity. Granule uniformity is a crucial contributor to quality fertilizer.
- Caking and clumping.
- Micronutrient/macronutrient segregation.
- Subsoil compaction.
- Fertilizer spreader.

Or

1. Soil Supplying Power:

Growing different crops during different seasons alters the soil nutrient status, estimated by soil analysis at the beginning of the season. The soil supplying power increases with legume in rotation. Fertilizer application and addition of crop residues. The available nitrogen and potassium in soil after groundnut are higher to initial status of the soil. But after pearl millet, only potassium status in the soil is improved and no changes in P.

2. Nutrient Uptake by Crops:

The total amount of nutrients taken by the crops in one sequence gives an indication of the fertilizer requirement of the system. The balance is obtained by subtracting the fertilize applied to crops that nutrient taken by the crops.

3. Residual Effect of Fertilizers:

The extent of residues left over in the soil depends on the type of fertilizer used. Phosphatic fertilizer and FYM have considerable residue in the soil, which is useful for subsequent crops. The residues left by potassium fertilizers are marginal.

4 Legume effect:

Legumes add nitrogen to the soil in the range of 15 to 20 kg/ha. The amount of nitrogen added depends on the purpose. Green gram grown for grain, contributes 24 and 30 kg N respectively to the succeeding crop. Inclusion of leguminous green manures in the system add 40 kg to 120 kg N/ha. The availability of phosphorous is also increased by incorporation of green manure crops. Potassium availability to subsequent crop is also increased by groundnut crop residues: crop residues add considerable quantity of nutrients to the soil, cotton planted in finger millet stubbles benefits by 20 to 30 kg/ha due to decomposition of stubbles. Deep rooted crops- cotton, red gram absorbs nutrients from deeper laers. Leaf fall and decomposing add phosphorus to op layers crop residue contain

high C: N ratio like stubbles of sorghum, pearl millet temporarily immobile nitrogen. Residue of legume's crop contains low C: N ratio and they decompose quickly and release nutrients.
Efficiency of crops: jute is more efficient crop for utilizing of nitrogen followed by summer rice, maize, potato and groundnut in that order.

5. Water management:
There is no carry over effect of irrigation as in case of fertilizer, rice – rice is efficient cropping system for total yield, but it consume large amount of water especially in summer. If water is scare in summer instead of rice, groundnut is used in cropping system.
Method of irrigation: the layout should be so planned that most of the crops can be suitable, in rice- rice- groundnut system; rice is irrigated by flood method, while groundnut by boarder strips. In cotton – sorghum- finger millet system, cotton, sorghum by furrow method while finger millet checks – basin method is adopted.

6. Weed management:
Weed problems observed individual crop, and weed shift occur and their carry over effect of weed control method on succeeding crop. Weeds are dynamic in nature, generally broad-leaved weeds occur in wheat occur in wheat at later stage and 2, 4 D is applied as post emergence herbicide to control them. In rice- wheat system, canary grass (phallaris minor) is a menace for wheat crop. Herbicide applied to the previous crop may be toxic to the succeeding crop. Higher dose of Atrazine applied to sorghum crop affect germination of succeeding pulse crops.

7. Pest and Diseases:
Pest and diseases infestation more in sequence cropping due to continuous cropping, carry over effect of insecticides is not observed.

8. Harvesting:
In sequences cropping crop can be harvested at physiological maturity stage instead of harvesting maturity. The field can vacate one week earlier. Because of continuous cropping the harvesting time may coincide with heavy rains and special post-harvest operations, like artificial drying, treating the crop with common salt etc. are practices to save the produce.

Factors affecting fertilizer application

1. **Indigenous Nutrient supplying capacity of soi**l: Fertile vs less fertile soil
2. Nature of crops: Exhaustive Vs non exhaustive crop, cereal vs legume crops, hybrid vs local varieties.
3. Soil moisture content: Irrigated vs rainfed
4. Manures and green manure applied
5. Biological nitrogen fixation
6. Crop residues recycled

Time of Fertilizer and manure application

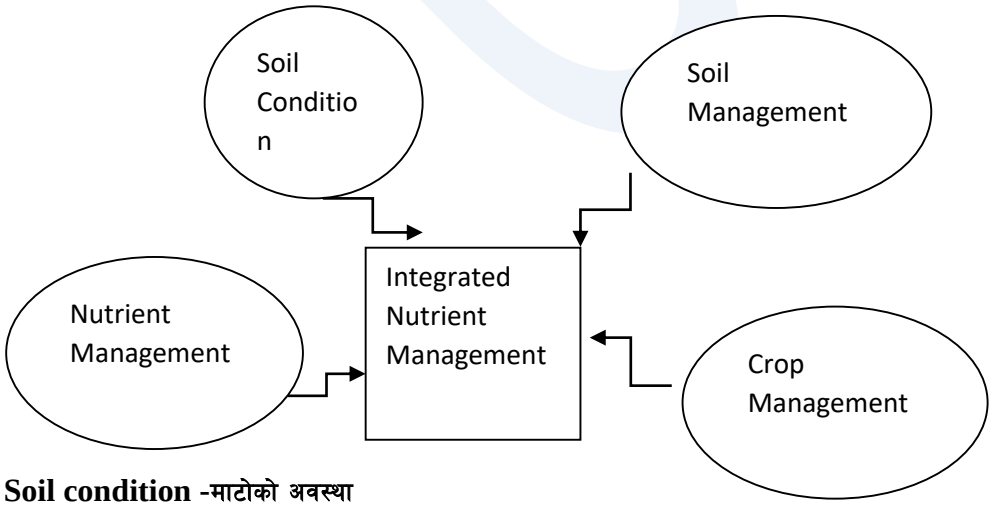
1. Manures/ compost/ green manures: It may require several days to release nutrients to crops. Therefore, these manures should be applied earlier at least 15-30 days before planting crops.

2. Nitrogen is mobile and liable to loss from the field through leaching and runoff, volatilization, denitrification and fixation. Therefore, nitrogen should be applied in split dose or real time crop requirement through use of leaf color chart (LCC), or through the use of SPAD
3. All other mineral elements have lower chance of loss from the soil, therefore, these mineral elements can be applied at the time of planting of crops or basal application.

LCC or SPAD BASED NITROGEN APPLICATION

- Leaf color chart measure the chlorophyll content, N is applied when it show N deficiency.
- Similarly SPAD also measure Chlorophyll, if the value of SPAD is less than certain pre determined value, N is applied.
- These provides techniques when to apply N in crops**.**

Integrated plant Nutrient Management (IPNM)



Soil condition -माटोको अवस्था
#Soil texture – माटोको बनोट
#Soil structure – माटोको संरचना
#Soil ph – माटोको पि. एच व्यवस्थापन
#Present OM – प्राङगारीक पदार्थको उपस्थीती

Soil management -माटोको ब्यवस्थापन
#Reduce of soil erosion – भुक्ष्य घटाउने
#Balance of soil ph – माटोको पि एच सन्तुलन गर्ने

#Balance OM – प्रागारीक पदार्थको व्यवस्थापन #Reduce leaching nutrient – चुहावट घटाउने
#Tillage management – खनजोत व्यबस्थापन

Crop management -बाली ब्यबस्थापन
#Crop rotation – बाली चक्र
#Evolution crop required nutrient – खाद्य तत्वको मुल्याङकन
#Selection suitable crop - सहि जातको छनोट # Intercropping system – अन्नतर बार्ला k|0ffnL
Plantation timing – समयमा राप्ने #Moisture management – चिस्यान व्यबस्थापन
#Weed management – झारपात व्यबस्थापन #Insect's pests, management – किरा र रोग व्यबस्थापन

Nutrient management -खाद्य तत्व ब्यबस्थापन
#FYM compost – गोठेमल #Green manure – हरीयोमल
#Plant reduce management – विस्वाको अवशेषको व्यबस्थापन #Chemical fertilizer – रसायनीकमल

5 Seed & Sowing
Seed

- A fertilized ripened ovule
- A young plant packed and ready for transport to wherever it may be wanted to start growing
- Part of flowering plant that contains embryo and develops into a new plant if sown
- Matured ovule in a dormant state, of a plant where the metabolic, synthetic and morphogenetic activities are suspended
- Anatomically- an embryo plant consisting of a rudimentary stem and root together with a supply of food sufficient to establish a plant in new location, all encased in a protective coat
- Physiologically- Essentially a meristematic axis with storage organs covered with membranes and the outer one is the seed coat.
- Is a unit of reproduction of flowering plants
- Agronomically, seed/seed material/ propagule is the living organ(s) of the crop in rudimentary form that is used for propagation, or in other words, any part of the crop from which a new crop will grow.

Define seeds

- Seed is a material which is used for planting or regeneration purpose. However scientifically, Seed is a fertilized matured ovule together covered with seed coat is called seed or it is a propagating material i.e., part of agriculture, sericulture, silviculture and horticultural plants used for sowing or planting purpose. Structurally a true seed is a fertilized matured ovule, consisting of an embryonic plant, a store of food and a protective seed coat, a store of food consists of cotyledons and endosperm

- Technically, seed may be sexually produced matured ovule consisting of an intact embryo, endosperm and or cotyledon with protective covering (seed coat). It also refers to propagating materials of healthy seedlings, tuber, bulbs, rhizome, roots, cuttings, setts, slips, all types of grafts and vegetative propagating materials used for production purpose.

Seed quality is the degree of excellence in regard to the characteristics mentioned below. If seed lots are genetically pure seed with high germination percentage, minimum number of inert matters/ weed & other crop seeds and are free from diseases., it is considered as high quality seed lot. Generally the standards fixed for certified seeds are considered quality standards. It implies that a if a seed lot meets the certification standard, it is good quality seed and if does not meet the certification standards, it is obviously of a lower seed quality.

Comparison between Seed and Grain

Parameters of Comparison	**Seed**	**Grain**
Definition	An ovule which contains the embryo.	Product of fusion of seed coat and fruit.
Purpose	Growing other plants	Human consumption
Components	The seed coat, embryo and endosperm	Bran, endosperm, seed coat, and embryo
Food	Embryo	Fruit part
Uses	Oil extraction	Making flour and cereals
Treated	Treated fungicide or insecticide	Not treated fungicide or insecticide
Viability	Viability is important	Viability is not important
E.g.	Rice seed, Pumpkin seeds etc.	Rice, Wheat etc.

Characteristics of quality seed:

1 Physical purity

- It should be clean and processed.
- It should be free from inert material, husks and broken seed.
- It should be free from weed seed of other variety and crops.

2 Genetic purity

- There should not be any genetic determination in the seed .
- This means that its genetic potential must be maintained.
- The variety should be true to the type (no varietal mixture).
- It should be distinct uniform and stable (DUS).
- There should not be off type plants.

3 Uniform shape, size & colour

- In fact, it is not necessary that large seed size always produce higher yields.
- In wheat, it has been observed that plants from small seeds having similar populations and good field conditions can produce an equivalent yield of grain as large seeds.

4 Proper moisture contain

Moisture content is very important. It is the key factor in determining whether or not the seed will retain its germination from harvest to sowing time. Moisture can be determined in the laboratory. Moisture meters can help make quickly on the spot assessment of moisture expressed as percentage by weight.
Optimum moisture content
Cereals: 10-12%
Pulses: 7-9%
Vegetables: 6-7%
Oilseeds: 5-6%

5 Well matured

Proper sees mature necessary.

6 High germination capacity

The germination capacity indicates the potential of a seed lot to establish as seedlings under good field conditions. A lot with high purity will be of no use for sowing if the seeds are incapable of germinating and producing strong seedlings in the field. The germination capacity of a seed lot is the percentage by number of pure seeds, which produce normal seedlings in a laboratory test.

8 Free from disease & pest

- It should be free from insects and diseases.
- It should be free from internal and external seed borne diseases.
- It must be free from larva, eggs of insects .There should not be insects made holes.
- Seed should be treated with proper chemicals against insects and diseases.

8 Not dormant/Viable

Seeds are easily viable in soil.

9 Not too much old

Old seed are not use for new plant germination.

IMPORTANCE OF QUALITY SEED

Seed is the basic input in the crops production .If seed quality is poor productivity can be increased even applications of all other inputs. It reduce the amount s of seed requirement .High quality produce is possible only when quality is high .It also reduce the chances of insects diseases and weed infection.

1. Ensures genetic and physical purity of the crops.
2. Gives desired plant population.
3. High return per unit area as the genetic potentiality of the crop can be fully exploited.
4. Capacity to withstand the adverse conditions.
5. Seedlings produced will be more vigorous, fast growing and can resist pest and disease incidence to certain extent.
6. Ensures uniform growth and maturity.
7. Development of root system will be more efficient that aids absorption of nutrients efficiently and results in higher yield.
8. High produce value and marketability.
9. Easy handling in postharvest operation and yield prediction.
10. It will respond well to added fertilizer and other inputs.
11. Good quality seeds of improved varieties ensures higher yield at least by 10 – 12 %.
12. Minimize seedling rate and maximize seedling emergence.

Different classes of seed

A Nucleus seed

- It is producer by breeder.
- It is the initial amount of pure seed of improved variety.
- This is the 100% genetically purity.
- This is the 100% physical purity.
- Small amount amounts.
- No certificate.
- Produce breeder seed.
- It has tag less.

B Breeder seed

- Progeny of nucleus seed.
- Direct regulator breeder.
- Sponging plant breeder of breeding program or intuition.
- It is the source for the increases of foundation seed.
- This is also 100% physical purity
- It is 100 genetically purity.
- Produce from institution or NARC.
- Border seed is visible in small quantity.
- Not certificate.
- It black clotted word & Brown tag (13.5cm X 8.5cm).

C **Foundation seed**

- Progeny of Breeder seed.
- In Nepal it is produced the farms of Gov. Farm/Group/Private Sector etc.
- It is source for the production of certified seed.
- It available in limited quality.
- This is also 99.5%/99.9% genetic purity.
- It is also 98% physical purity.
- It seed for production of foundation seed.
- Certification (Seed certification agencies verify).
- A white colour certificate is issued for foundation seed by seed certification agencies.
- It black clotted word & white tag (13.5cm X 8.5cm).

D Certified seed

It is produced from foundation seed. This type of seeds are two type seeds.

Certified seed 1 (1 generation)

- It is progeny of foundation seed.
- Certification (Seed certification agencies verify).
- It available in good amount.
- This is also 99% genetic purity.
- It is also 98% physical purity.
- It blue clotted word & white tag (13.5cm X 8.5cm).

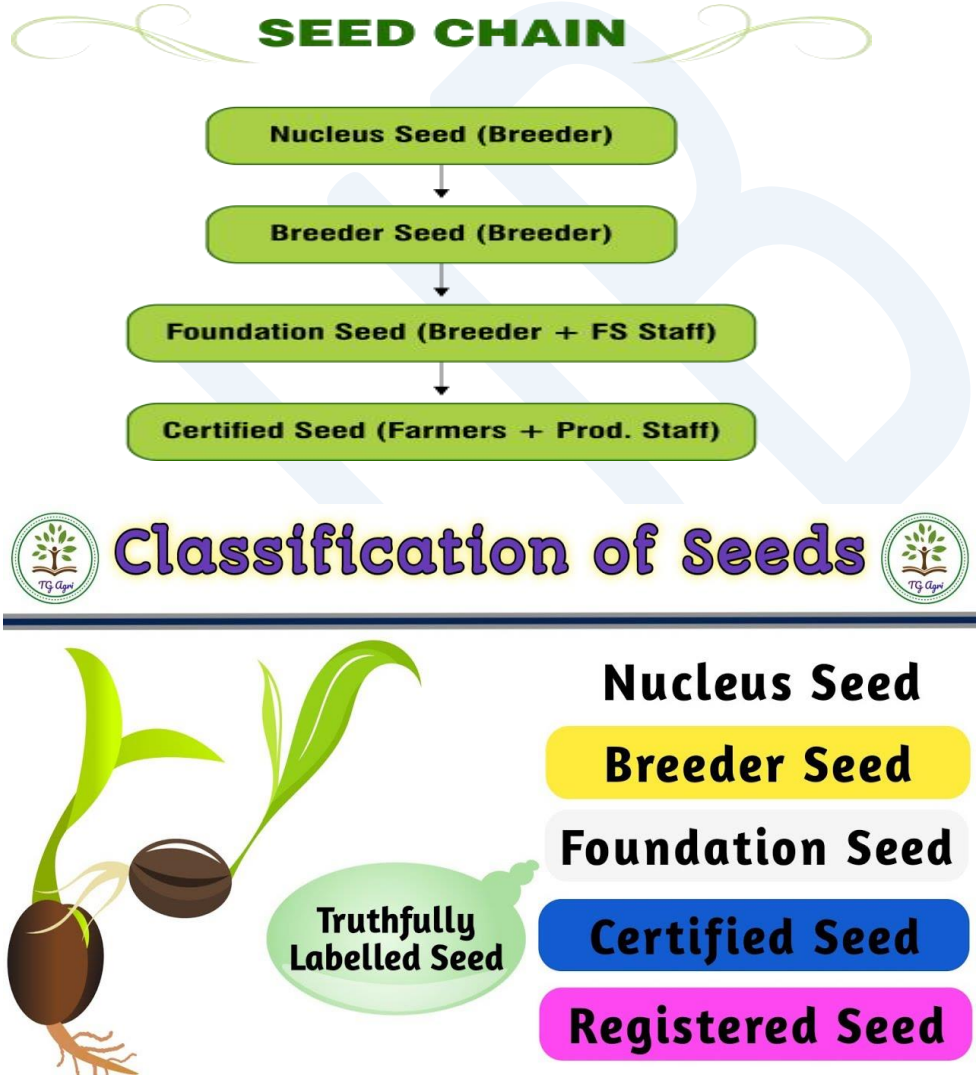
Certified seed 2(2generation) - (Only potato

- It is the progeny of certified seed.

- It is produced I the seed growing farmers field supervision of seed agencies.
- It has tag with green border.
- It is source seed for improved seed production.
- It is available in sufficient quantity.
- It blue clotted word & white tag (13.5cm X 8.5cm).

E Improved seed-

- It is progeny of certified seed.
- It is produced field with supervision of certifying agency.
- It is available is sufficient.
- It has for cultivation of crops.
- It black clotted word & yellow tag (13.5cm X 8.5cm).



Types of Seeds

- **Food crops seeds:** Major food crops whose seeds are multiplied commercially are: Rice, maize, wheat, finger millet, barley, buckwheat, pulses and oil seeds. Seeds of these food crops are almost similar to the grains at harvest. Therefore, many crop growers are also potential seed producers. This implies that a farmer does not buy food grain seeds but buys a better seed of a variety. Another notable aspect of such crops is that farmers may

buy a small quantity of a new variety seed in order to further multiply it over several generations. Both these aspects affect the volume of sales and actual seed replacement rates (SRR). Use of hybrid seeds especially maize and rice is on the rise in Nepal.

- **Vegetable seeds:** Unlike food grains, vegetables are grown for specific consumption purposes such as leaf, flower, pod and root that determine the popularity of a particular crop. Many locally popular vegetables are cross pollinated and recommended isolation distance maybe more than one kilometer. Another important characteristic is that their seed rate is low (except for peas and beans). Most of the vegetable seeds are regarded as high value low volume commodity with specific production requirement. In Nepal, seed replacement rate for vegetable crops was as high as 66 percent in 2009 and hybrid seed use is increasing.

- **Forage and pasture seeds:** Demand for forage seeds has increased recently in order to provide for an increasing need of animal feeds due to growth of dairy and commercial livestock production. The extent of animal feed deficit is estimated to be about 36-40 percent in Nepal, and is expected to be fulfilled through increased forage production. Sufficient production of forage and pasture seeds is crucial to increase forage and pasture production, fulfil nutritional requirement of livestock population, and reduce the animal feed consumption. The reducing use of animal feed helps to lower the cost of meat and dairy products as the cost of production of these products is low when livestock production is based on forage and pasture crops.

- **Cultural crops seeds:** Seeds of certain crops or varieties are important from cultural aspects, such as barley, sesame, and anadi rice. Seed multiplication of these crops or varieties is necessary to maintain religious or cultural values.

- **Other crops seeds**: Other important crops are jute, sesame, niger, cotton, tea and coffee, flower, spices and trees seeds.

- **Other planting materials:** Specific parts of potatoes (tubers), ginger (rhizomes), sugarcane (stems) and fruit and forest trees (saplings, cuttings, suckers, grafting) are used as planting materials.

Seed germination

Seed Germination is the resumption of growth by embryo & development of a young seedling from the seed. Germination is an *activation of dormant embryo to give rise to radical (root development) and plumule (stem development*). Germination is the awakening of the dormant embryo. The process by which the dormant embryo wakes up & begins to grow is known as Germination.

Seed Emergence : Seedling actually coming above and out of the soil surface.

Changes During Germination:

1) Swelling of seed due to imbibition of water by osmosis.
2) Initiation of physiological activities such as respiration & secretion of enzyme.
3) Digestion of stored food by enzymes.
4) Translocation & assimilation of soluble food leading to development of embryo axis into seedling

When seed is placed in soil gets favorable conditions, radical grows vigorously & comes out through micropyle & fixes seed in the soil. Then either hypo or epicotyls begins to grow.

Types of germination:

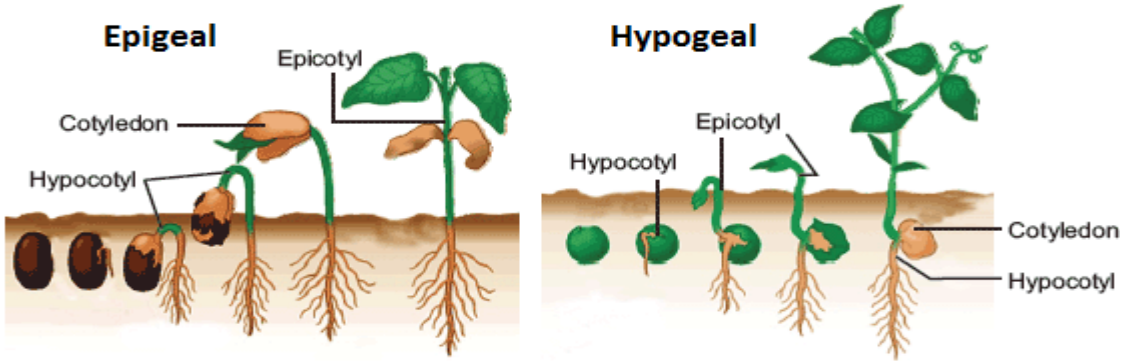
1. Hypogeal germination:
2. Epigeal germination:

Epigeal

- The cotyledons come out of the soil (beans, sunflower, mustard, onion, tamarind)
- The plumule remains enclosed and protected by cotyledons till it comes out of the soil.
- The cotyledons become green and function as the first leaves of the seedling.

Hypogeal

- The cotyledons remain inside the soil (e.g. Gram, Mango, Pea, maize, wheat, rice)
- There is no such provision.
- The cotyledons do not take part in photosynthesis.



Facture affecting seed germination
EXTERNAL FACTORS:

1. **Moisture**: It enables the resumption of physiological activities, swelling of seed due to absorption of moisture & causes bursting of seed coat & softening the tissue due to which embryo awakes & resumes its growth.

2. **Temperature:** A suitable temperature is necessary for proper germination. Germination does not take place beyond certain minimum & maximum temperature i.e. 0ºC & above 50ºC. Optimum temperature range for satisfactory germination of seed is 25 to 30ºC.

3. **Oxygen:** It is essential during germination for respiration & other physiological activities which are vigorous during the process.

4. **Substratum:** It is the medium used for germinating seeds. In the laboratory, it may be absorbent paper (blotting paper, towel or tissue paper), soil & sand. Substratum absorbs water & supplies to the germinating seeds. It should be free from toxic substances & should not act as medium for growth of micro-organisms.

5. Light:

Photoblastic Seed: Are the seeds which respond to light for their germination. Three categories of photoblastic seeds are recognized:

1. *Positive photoblastic Seeds*: Seeds require exposure to sunlight (may be for a brief period) for germination and do not germinate in darkness (lettuce, tobacco, mistletoe, etc.).

2. *Negative photoblastic* : Seeds do not germinate if exposed to sunlight (onion, lily, Amaranthus, Nigella, etc.).

c. *Non-photoblastic Seeds*: Non-photoblastic seeds germinate irrespective of the presence (exposure) or absence (non-exposure) of light.

INTERNAL FACTORS:

1. Food & Auxins: An Embryo feed on the stored food material until young seedlings prepares its own food. Auxins are the growth promoters, hence quite essential during the germination.

2. Viability: All seeds remain viable for certain definite period of time and thereafter embryo becomes dead. It depends on maturity of seed, storage conditions & vigour of parents and type of species. Generally, it is for 3-5 years and they remain for more than 200 years also as in lotus.

3. **Dormancy:** It is the failure of mature viable seed to germinate under favorable condition of moisture. Many seeds do not germinate immediately after their harvest, they require rest period for certain physiological activities.

Seed Dormancy

Is failure of fully developed & mature viable seed **to germinate** under favorable conditions of moisture & temperature is called **resting stage** or dormancy and the seed is said to be dormant.

Kinds of Dormancy in Seeds:

1. Primary dormancy: The seeds which are capable of germination just after ripening even by providing all the favorable conditions are said to have primary dormancy. E.g.: Potato.

2. Secondary dormancy: Some seeds are capable of germination under favorable conditions just after ripening but when these seeds are stored under unfavorable conditions even for few days, they become incapable of germination.

3. Special type of dormancy: Sometimes seeds germinate but the growth of the sprouts is found to be restricted because of a very poor development of roots & coleoptiles.

Causes of seed dormancy:

There are certain major causes for the seed dormancy. Listed below are the few reasons for the seed dormancy.

- Light
- Temperature
- Hard Seed Coat
- Period after ripening
- Germination inhibitors

- Immaturity of the seed embryo
- Impermeability of seed coat to water
- Impermeability of seed coat to oxygen
- Mechanically resistant seed coat
- Presence of high concentrate solutes

Or

1. Seed coats being impermeable to water: Such seeds even when fully matured & placed in favorable conditions; fail to germinate because of failure of water to penetrate into the hard seed coats. These seeds become permeable, if they are treated with H2SO4 or dipped in boiling water for few seconds. E.g.: Cotton.

2. Hard seed coat: Seeds of mustard, amaranths, etc. contain a hard & strong seed coat which prevents any appreciable expansion of embryo. Thus, if the seed coats fail to burst the embryo will remain dormant even after providing all the favorable conditions for germination.

3. Seed coats being impermeable to Oxygen: The seed coats are impermeable to O2 & if the seed coats do not rupture the seed fails to sprout.

4. Rudimentary embryo of seeds: The seeds which are apparently ripened contain a rudimentary or imperfectly developed embryo and the germination of such seeds naturally gets delayed until the embryo develops properly

5. Dormant embryo: The seeds of an apple, peach, pinus, etc do not germinate even though the embryos are completely developed and all the favorable conditions for germination are provided. In such seeds, physiological changes called after ripening take place during the period of dormancy which enables the seeds for germination.

6. Synthesis & accumulation of germination inhibitors in the seeds: Plant organs synthesize some chemical compounds which are accumulated in the seeds at maturity and these chemicals inhibit the germination of their seeds. Pulp/glumen

7. Dormancy due to envtal factors: Some seeds require light for germination while other germinates only at dark. Similarly some may require altering dark and light period to germinate. Some require chilling treatment (low temp) whereas some need combination of high and low temperature to germinate.

Methods to Break the Dormancy

1 SCARIFICATION: The dormancy due to hard seed coat or impermeable seed coats can be broken by scarification of seed coats. It should be done in such a way that the embryo is not injured.

a. Chilling (Pre-chilling): The seeds are placed in contact with the moist substratum at a temperature of 5 to 10°C for 7 days for germination. E.g. Cabbage, Cauliflower, and Sunflower.

b. Pre-dying: Seeds should be dried at a temperature not exceeding 40°C with free circulation for a period of 7 days before they are placed for germination. E.g. Maize, Lettuce.

c. Pre- washing: In some seeds, germination is affected by naturally occurring substances which act as inhibitors which can be removed by soaking & washing the seeds in the water before placing for germination. E.g.: Sugar beet.

d. Pre-soaking: Some seeds fail to germinate due to hard seed coat. Such seeds should be soaked in warm water for some period so as to enhance the process of imbibitions.

e. Rubbing or puncturing seed coat: Some seeds are subjected to mechanical scarification either by rubbing them against rough surface/sand/sandpaper or puncturing the seed coat with pointed needle. E.g.: Coriander, Castor.

f. Impaction: Vigorous shaking of seeds to remove the cork like substances, strophiolar plug, which prevents the penetration of oxygen ad water.

2. STRATIFICATION: In some seeds after ripening, low temperature and moisture conditions require in artificial stratification. Seed layer altered with layers of moist sand or appropriate material to store at low temperature. E.g.: Mustard & Groundnut. (Low temp. in moist condition in +nce of oxygen)

3. EXPOSURE OF SEEDS TO LIGHT: It also helps to break the dormancy & increase the germination.

4. CHEMICAL TREATMENTS:

a. Potassium nitrate treatment (KNO3): The material used for placing the seeds for germination i.e. substratum, may be moistened with 2% solution of KNO3 (2g KNO3 + 100ml of water). E.g. Rice, tomato, chilies.

b. Gibberellic acid treatment: The substratum used for germination may be moistened with 500 ppm solution of GA i.e. 500 mg in 1000ml water. E.g. Wheat, Oat.

c. Thio-urea treatment: Potato tubers are dipped in thio-urea solution (1%) for one hour when fresh harvested produce is to be used as seed material.

6 Tillage

Tillage

Tillage/land preparation is the manipulation of the soil into a desired condition by mechanical means; tools are employed to achieve some desired effect (Eg: Pulverization, cutting or movement).

Tillage is the mechanical manipulation of the soil for obtaining conditions ideal for seed germination, seedling establishment and growth of crops.

Jethrotull is the father of tillage.

Tilth is the good physical condition of soil after tillage in relation to plant growth.

Tillage is the process of preparing soil for cultivation purposes and varies considerably around the world.

a. Tillage is done to change its structure (decrease ped/clod size; to facilitate intake, storage and transmission of water and to provide good environment for seeds and roots)-facilitate aeration

b. Tillage is done to kill/control weeds (as weeds compete for water, nutrients and sunlight)

c. Tillage is done to manage crop residues i.e. remove, incorporate or modify plant residue (to provide conditions suitable for seeding and cultivating a crop)

d. Tillage is done to mix and incorporate soil amendments such as lime and basal fertilizers

History of Tillage

♣ Jethro Tull (1731) wrote a book "Horse Hoeing Husbandry".
♣ He is called father of tillage
♣ He believed that plant absorb/ eat minute soil particles from the roots.
♣ The more fine will be soil better will be crop growth and yield.
♣ Based on his work many kinds of cultivators and seed drills were developed.

Modern concept of tillage

♣ Edward Faulkner (1940) wrote a book "Plowman's Folly".
♣ He stated that plowing is unnecessary because:
- Increase soil erosion
- Destroy organic matter content of soil
- Destroy soil structure
- Disturb soil ecology and soil organism
- Reduce the productiveness of soil

Objective of Tillage

- A pest and pathogen free environment.
- Mixing the applied manures and fertilizers with the soil, and
- Removing the hard pan, if any to increase the soil depth for water absorption.
- Obtain conditions that would guarantee a better yield
- Better soil aeration for better gaseous exchange both in soil and root area
- Improvement of soil structure and permeability
- Demolition of pests
- Preparing soil for more water absorption
- Uniform distribution of manure and fertilizers.
- Create a setting where the seedling gets maximum sunlight necessary for growth(Through weed control)
- Provide efficient seed-soil contact in a way the seeds and seedling gets adequate water.
- Increase soil depth
- Mix fertilizer
- Crust breakdown
- Proliferation
- Weed control
- Removing hard soil pan
- Good soil condition

Soil Tilth is the term used to express soil condition resulting from tillage. Hence it is the resultant of the tillage. A soil is said to be in good Tilth when it is soft, friable & properly aerated.

Soil Tilth is that kind of physical condition of soil when it is loose. Not very powdery but granular & when these granules are felt between fingers they are soft, friable, & crumble easily under pressure.

Such soils permit easy infiltration of water & are retentive of moisture for satisfactory growth of plants.

Tilth is the physical condition of the soil brought out by tillage that influences crop emergence, establishment, growth and development.

Tilth is a loose, friable, airy, powdery granular & crumbly structure of the soil with optimum moisture content suitable for working & germination or sprouting seeds & propagates.

Characteristics of good soil

- 'It is the physical condition of soil resulting from tillage & said to be good when the soil is soft, friable and properly aerated.'
- Should have higher % of larger aggregates (more than 5 mm diameter) for irrigated farming.
- Should have higher % of smaller aggregates (1-2 mm diameter) for dry-land farming.
- Should be porous & has free drainage up to water table.
- Micro-pores (capillary) & Macro-pores (non-capillary) should be in equal proportion.
- The soil particles should not be easily eroded by water or wind.
- Soil should not be sticky when moist.
- Soil should permit easy infiltration of water.

Soil tilth can be measured by following methods:

- Feel and appearance method
- Pore space content -equally divided in micro & macro pores
- Measuring size of soil aggregates -best size of soil aggregates ranges from 1 to 6 mm.

Type of tillage

1 PRIMARY TILLAGE:

The tillage operation which constitutes the initial major soil working operation. It is normally done to *reduce soil strength, cover plant material* and *rearrange aggregates*.

1. To open hard soil
2. To invert the soil
3. To uproot weeds and stubbles
4. To break the hard pans

♣ Time of primary tillage operation:

- Beginning of cropping season
- After harvest of crop.

It depend upon soil moisture content:

When soil is too dry and heavy texture:
- difficult to open soil
- More energy is required
- Large size clods result

♣ When soil is wet:
- Soil sticks to the plow
- Plow sole becomes compacts
- Hard pan formation
- Clods after drying become very hard

Optimum soil moisture range for plowing:
- 25 – 50 % depletion of available soil moisture.
- Lighter soil can be plowed any time

♣ Depth of Primary Tillage
♣ Depth of operation depends upon effective root zone of crops.
♣ Very commonly used depth: 15 – 30 cm
♣ Western country: 50 - 70 cm
♣ Deep rooted crop: 25 -30 cm
♣ Moderate depth: 15 -20 cm

Common primary tillage implement:
- Mould board plow
- Disk plow
- Sub soil plow
- Chisel plow

Soil condition after primary tillage operation:
- Filed looks cloddy
- Land not suitable for seed

2 SECONDARY TILLAGE:
Tillage operations done after primary tillage to create proper soil tilth for seeding and planting are secondary tillage.
It is done to improve seedbed by increased soil pulverization, to conserve moisture through destruction of weeds, and to cut up crop residues.

Purpose of secondary tillage:
- To make the soil finer
- Incorporate crop residues, weeds, fertilizers and manures.
- Level the field
- Bring the soil under good tilth

Depth of Secondary tillage:
- Shallower depth: 10- 15 cm

Secondary tillage implements:
- Disc harrow
- Cultivator
- Leveler
- Ridger
- Seed cum fertilizer drill
- Seed dril

3 Inter tillage/ Inter cultivation/ Inter culture/ after care operation:

The tillage operations carried out in the standing crop are called inter tillage operations.

The tillage operation done in the field after sowing or planting and prior to the harvesting of crop plants known as inter cultivation.

It includes *gap filling, thinning , weeding , mulching, top dressing of fertilizers, hoeing, earthling up* etc.
Tillage that is carried out in the period between planting/ sowing of seed and harvesting of crops. ♣ **Purpose**

- To control weeds
- To provide aeration
- To provide anchorage
- To provide space for tuber development

Inter tillage implements

- Rotatory weeder
- Ridger
- Cultivator
- Kuto
- Hand hoe

Depth of tillage 5 – 7 cm

Tillage Implements and their works:

- a. Chisel plough- Subsoil breaking
- b. Rotary plough – Cut and pulverizes the light soil
- c. Ridge plough – Earthling-up and form ridges and furrows
- d. Basin luster – Prevent runoff and form basins
- e. Disc plough – Deep ploughing in grassed field
- f. Tractor drawn cultivator – Destroy weeds and breaking clods
- g. Sweep cultivator – Harvesting groundnut and used in stubble mulching
- h. Harrows – Preparation of seedbed, destroy weeds
- i. Flanker – Micro leveling
- j. Star weedier – Weeding in dry lands and groundnut
- k. Potato digger – Used to harvest potatoes
- l. Groundnut digger – Used to harvest G'nut

Kinds/ types/Methods of Tillage
A Conventional Tillage: Some farmers use machines like a plow or disc to turn over and loosen the soil after harvest (a process called tillage). This can leave the soil exposed to rain and wind, which can sometimes lead to erosion (wearing away) of the topsoil that is needed to grow a crop.

1 Conservation Tillage: This is a technique for planting seed that minimizes the disruption of soil and therefore helps prevent soil erosion.

- Based on Jethro Tull
- Old concept of tillage
- Soil tilth is fine and clean

- No debris or crop residues over soil surface
- Primary- secondary – inter tillage carried out
- Plowing- harrowing- leveling- inter tillage
- Use of M.B plow- harrow- leveler- ridger- seed drill- inter-culture like use of Rotatory weeder

Kinds/ types of Conservation Tillage

1 Minimum or Reduced tillage
2. Zero or No tillage
3. Stubble mulch tillage

1. MINIMUM TILLAGE:

It is aimed at reducing tillage operations to the minimum necessary for ensuring a good seedbed, rapid germination, a satisfactory stand & favorable growing conditions, Tillage can be reduced by:

1 By reducing/omitting tillage operation that is not beneficial
2. By combining two or more than two agricultural operation together.

Kinds of Minimum Tillage

1. Row Zone Tillage

♣ This types of tillage system is practiced in wide spaced crops like sugarcane, maize, soybean, sunflower and potato etc.
♣ Primary tillage operation may be carried out with M. B. plow to invert soil for reducing weeds and stubbles.
♣ Secondary tillage operation is done in the row zone only to ensure planting and crop establishment.
♣ The inter row space remain cloddy with some amount of crop residue over the surface.
♣ There is no need of harrowing, pulverizing and leveling of inter space zone of soil.
♣ Thus, the number of tillage operation and area of tillage is reduced

2. Plow- plant tillage

♣ Tillage system where two or more than two agronomic operations are combined together to reduce the number of tillage operation.
♣ Primary tillage operation may be carried out and secondary tillage like fertilizer placement, seeding, seed covering and leveling are combined in one.
♣ Ex. Seed cum fertilizer drill.

Advantages of Minimum tillage:

1) Improve soil condition due to decomposition of plant residues *in situ*,
2) Higher infiltration caused by decomposition of vegetation present on soils & channels formed by decomposition of dead roots.
3) Less resistance to root growth due to improved structure.
4) Less soil compaction by reduced movement of heavy tillage vehicles.
5) Less soil erosion compared to conventional tillage.

Disadvantages of Minimum tillage:

1) Less seed germination,
2) More 'N' has to be added as rate of decomposition of organic matter is slow.
3) Nodulation may affect in some legumes.
4) Sowing operations are difficult with ordinary implements.

2. ZERO TILLAGE:

Zero-tillage is the extreme form of conservation tillage resulting in minimal disturbance to the soil surface.

♣ Minimum soil disturbance is done to place seed and fertilizer only.
♣ Primary and secondary tillage operation is not carried out.
♣ Weeds and stubbles are controlled through the use of herbicides.
♣ Generally broad spectrum herbicide like Gglyphosate (1 Kg a.i./ha or 5 ml/ liters of water) with spray volume of 600 – 1000 liters is sprayed 7 -15 days before planting.

It is done where:
1) Soils are subjected to wind & water erosion,
2) Timing of tillage operations is too difficult &
3) Requirements of energy & labor for tillage are too high.

Advantages of zero tillage:
1) Soils are homogenous in structure with more no. of earth worms.
2) Organic matter content increased due to less mineralization.
3) Surface runoff is reduced due to presence of mulch. Several operations are performed by using only one implement. In these weeds are controlled by spraying of herbicides**.**

Disadvantages of zero tillage:
1. Higher 'N' is to be applied due to slower decomposition of org. matter.
2. Large population of perennial weeds appears.
3. Build up of pests is more.

3. Stubble Mulch Tillage

♣ It is year round system of managing the crop residues with implements that under cuts residue, loosen the soil and kills weeds.
♣ This system use a wide sweep and trash bars to clear a strip and a narrow planter is used to open furrow to place seed.
♣ The seed and fertilizer placement can be done together in two furrow open by planter.
♣ All the residues of previous crops are kept on inter row space.
♣ Weeds are controlled through the use of herbicides.

***3.a. Mulch- till*:**
The soil is protected at all times either by growing a crop or by crop residues left on the surface during fallow periods. It is year round system of managing plant residue with implements that undercut residue, loosen the soil and kill weeds.
Soil is tilled as often as necessary to control weeds during the interval between two crops. However, it presents the practical problem as the residues left on the surface interfere with seedbed preparation & sowing operations.
Mulch-till is another form of reduced tillage system in which residue is partially incorporated using chisels, sweeps, field cultivators, or similar farming implements that leaves at least one third of the soil surface covered with crop residue.
3.b. Strip- till*:* Strip-tillage involves tilling the soil only in narrow strips with the rest of the field left untilled
***3.c. Ridge- till*:** Ridge-till involves planting seeds in the valleys between carefully molded ridges of soil. The previous crop's residue is cleared off ridge-tops into adjacent furrows to make way for the new crop being planted on ridges. Maintaining the ridges is essential and requires modified or specialized equipment

4. PUDDLING:

- Puddling is ploughing the land with standing water so as to create an impervious layer below the surface to reduce deep percolation losses of water and to provide soft seedbed for planting rice.
- Is done in rice. Maintaining standing water throughout the crop period is not possible without puddling.
- It aims at destroying soil structure and separates individual soil particles i.e. sand, silt & clay, during operation and settles later. The sand particles reach the bottom, over which silt particles settle & finally clay particles fill the pores thus making impervious layer over the compacted soil.
- It is done with several implements depending on the availability of equipment and the nature of land such as spade, wetland plough, mould board plough, wetland puddler, country plough, etc.
- It consists of ploughing repeatedly in standing water until the soil becomes soft & muddy. Initially, 5-10cm of water is applied depending upon the water status of the soil to bring saturation and above and the first ploughing is carried out after 2-3 days.
- By this operation, most of the clods are crushed and majority of the weeds are incorporated. Planking or leveling board is run to level the field.

Advantages of conservation tillage

- Increases the ability of soil to store or sequester carbon while simultaneously enriching the soil.
- Improves soil water infiltration, thereby reducing erosion and water and nitrate runoff.
- Improves the stabilization of soil surface to wind erosion and the release of dust and other airborne particulates.
- Reduces leaching of nutrients due to greater amounts of soil organic matter to provide binding sites.
- Decreases evaporation and increases soil moisture retention, which can increase yields in drought years (Suddick et al., 2010).
- Reduces the number of passages of equipment across the field, thereby reducing the cost of fossil fuel and the associated carbon emissions to the atmosphere.
- Reduces the loss of pesticides and other applied chemicals. This is because higher infiltration rates with more surface residue results in less runoff, moisture holding capacity due to higher soil organic matter that results in less leaching.

Disadvantages of Conservation tillage

- Adoption of reduced tillage in humid, cool soils would primarily affect the distribution of SOC in the profile, unless carbon inputs were increased (Lal et al., 1998).
- Specialized, expensive equipment is required, or much hand labor in the case of very small scale growers.
- Requires more herbicides and pesticides than standard conventional practices to control weeds and other pests.
- Due to the large size of the original soil carbon pools, the contribution of conservation tillage can appear to be small, and a significant amount of time is required to detect changes.
- Sizable amounts of non-CO_2 greenhouse gases (N_2O and CH_4) can be emitted under conservation tillage compared to the amount of carbon stored, so that the benefits of conservation tillage in storing carbon can be outweighed by disadvantages from other GHG emissions.

S.N	Conventional Tillage	Conservation Tillage
1.	Is Traditional method of farming in which soil is prepared for planting by completely inverting it with a tractor-pulled plough, followed by subsequent additional tillage to smooth the soil surface for crop cultivation.	Conservation tillage is a tillage system that conserves soil, water and energy resources through the reduction of tillage intensity and retention of crop residue.
2.	Excessive tillage leaves the soil susceptible to crusting, impedes water intake, increases runoff, and thus reduces water storage for crop use. Intensive vegetable production in warm climates where three crops per year may be grown on the same land may reduce the soil to a single-grain structure that facilitates surface cementation and poor aeration.	Conservation tillage involves the planting, growing and harvesting of crops with limited disturbance to the soil surface.
3.	Soil erosion high; reduced moisture content;	With this technique, at least 30% of the soil surface is covered with crop residue/organic residue following planting (Dinnes, 2004)
4.	The loosening and granulating actions of plowing may improve soil structure if the plowing is done when the moisture content is optimum; if not so timed, however, plowing can create unfavourable structure. The lifting and inversion of the furrow slice likewise may not always be desirable, because in many cases it is better to leave a trashy surface.	Conservation tillage methods include zero-till, strip-till, ridge-till and mulch-till. Zero-tillage is the extreme form of conservation tillage resulting in minimal disturbance to the soil surface.

B No-till/Zero Tillage: No-till works in the same way as conservation tillage, but there is less disruption of soil (e.g. the planter does not go as deep into the soil to plant the seeds, and no crop residue is turned over.) No-till practices are used in 56.4 per cent of all area prepared for seed in Canada.

No-till farming can reduce soil erosion by 90 to 95 % or more compared to conventional tillage practices and continuous no-till can make the soil more resistant to erosion over time. Studies have shown that soil under no-till agriculture sequestered on average 29% carbon than soil under conventional tillage.

Advantages of conventional tillage

- Opens up compacted soil, allows for vertical transfer of O.M., creates soil aggregates, decreases soil particles to create good seed bed

- Increase soil/air exchange and increases soil infiltration
- Increase temp of cold soils
- Incorporate organic matter, cover crops or crop residues
- Break up soil pans
- Control weeds
- Dry the soil before seeding

Disadvantages of conventional tillage

- Compaction of soil below the depth of tillage (hard pan)
- Soil loses nutrients and organic matter
- Reduced biological activity and loss of earthworm activity
- Destruction of soil aggregates
- Soil loses ability to store water and soil loses ability to drain well
- Loss of soil pore space
- Erosion of the soil
- Cost of tillage equipment and energy costs of tillage operation

7 Irrigation & Drainage

Irrigation

It is generally defined as application of water to soil for the purpose of supplying the moisture essential for normal growth and development. In other word it is the human manipulation of hydrological cycle to improve crop production and quality and to decrease the economic effect to drought. i.e Irrigation requirement = water requirement – (effective rainfall + soil available moisture. Then, Total water requirement = Transpiration + evaporation from soil +water used in metabolic process+water loss via run off , percolation etc + water required for land preparation and other purposed.

- Irrigation water comes from ground water through *springs/wells/surface water, rivers/lakes/reservoirs* or other sources like treated waste water or desalinated water.

- Goal of irrigation is to apply water to plants as uniformly as possible so that each plant receives exactly the amount of water it needs (neither too much nor less)

Principle of irrigation:

1. When there is adequate supply of water irrigation can provided any time so that the soil moisture can be maintained.
2. When water is in limited supply ,provide the irrigation at critical stage of crop.

Methods of irrigation

Irrigation generally three types as below:

1.Surface irrigation

2.Sub-surface irrigation

Why irrigation is done

Irrigation is done for following cause.

Ø To supply the moisture essential for plant growth.

Ø For better utilization of production factor (Nutrient).

Ø To provide crop insurance against short spells of drought.

Ø To dilute /washout soluble salt

Ø To soften tillage pans
Ø Intensive cropping system is made possible.
Ø Timely seeded preparation and timly sowing
Ø To create favorable microclimate for crop growth
Ø Higher yield as well as stability in production.

Water is one of the essential elements of human existence. It is not always possible to get water supply from natural sources. Here comes the application of irrigation supply. Irrigation is the man-made means of supplying water. The main objectives of irrigation supply are given below.

- Ensure enough moisture essential for plant growth.
- Provide crop insurance against short duration drought.
- Cool the soil and atmosphere to provide a suitable surrounding.
- Wash out or dilute harmful salt, chemicals of the soil.
- Reduce hazards of soil piping.
- Soften the tillage pan.

Explain about the different types of irrigation method.

1 Surface Irrigation
1.1 Flooding
1.2 Basin Irrigation
1.3 Furrow irrigation
1.4 Ring irrigation
1.5 Stripe Irrigation
2 Sub surface Irrigation
3 Pressurized Irrigation
3.1 Drip Irrigation
3.2 Sprinkler Irrigation
3.3 Mist Irrigation

Some of the different methods of irrigation are explained below:-

1.Surface irrigation

- Is suitable for relatively levelled land
- Water from irrigation channel located at upper reach of the field is allowed to the field. Water floods the soil and advances over the field as a sheet owing to the differences in level
- Thus it is application of water by gravity flow to the cultivated land wetting either the entire field or part of field
- For efficient application of water it is important to select such method of irrigation which fit ones own land
- This method is not suitable if infiltration of soil is >7.5cm per hr.

Eg. Flooding, Basin method, bed method/border strip method and furrow method

Surface irrigation can be sub-divided into furrow, border strip, basin irrigation or check basin method of irrigation.

1.a. Flooding :

- Is done where adequate water is available, flow of water is more and land is levelled
- Is common in rice growing areas-where irrigation is done by lands, plot size is large and water is filled filled in the plots

- Water is allowed from one plot to another plot.
- Labor cost is less
- Irrigation efficiency is less
- Unsuitable to crops that are sensitive to water logging

a. Bed Method/Border Strip method:

- Is suitable when slope of the field is <1%
- Applied when flow of water is more eg: water supply by boring and pumpset
- Flooding of water is controlled by dividing the field into several narrow land stripes that run over entire length of the field parallel to its uniformly graded slopes
- Stripes are bordered by shallow ridges
- Water from irrigation channel is allowed in one or more of these stripes
- Narrow width of stripes facilitates uniform advancement of water from its upper to lower end
- Water supply is cut off some minutes before the reaching of water front to the lower end of the plot

b. Basin Method or Check Basin Method:

Check Basin Irrigation:

- Field is divided into small plots surrounded by bunds on all four sides
- Water from head channel supplies water to two rows of check basins and water is applied to one basin after another
- Is common in close growing crops like wheat, finger millet, ground nut

c. Basin Irrigation:

Basin around the trees are irrigated. Is suitable for fruit crops Basins are connected by irrigation channels

d. Furrow Irrigation:

Water is allowed into 3-5 furrows from the channel at a time depending on the stream size.

Is done in vegetable crops, certain fruit crops planted on ridges and furrows. Eg: Potato, Sugarcane, Sugar beet

Advantage of surface irrigation

• Irrigation management is very easy and does not require modern technology and can largely build on local traditional knowledge;
• Adapts well to small land holdings and does not require high financial input;
• Adapts easily to flat topography and can function without outlet drainage facilities;
• Works well with short-term water supplies;
• Irrigation allows full utilization of rainwater and can achieve high application efficiencies;

Disadvantages of surface irrigation

• Requires level land to achieve high efficiencies (maximum land elevation fluctuation should not be greater than half the applied irrigation depth);

• Soils with high infiltration rates require small field sizes, which interferes with mechanization.
• Difficulty to apply small irrigation quantities, excess water is difficult to evacuate, particularly during times of excess rainfall;
• Plants are partly covered with water sometimes over extended periods (in low infiltration rate soils);
• Small basins require extensive delivery channels and are not easily adaptable to tractor mechanization.

2 Sub surface irrigation :

- Also called sub irrigation, involve irrigation to crops by applying water from beneath the soil surface either by constructing trenches or installing underground perforated pipe lines or tile lines

- Water is discharged into trenches and allowed to stand during the whole period of irrigation for lateral and upward movement of water by capillarity to the soil between trenches.

- Underground perforated pipe or tiles in which water is forced , trickle out water through perforations in pipes or gaps in between the tiles

- Water moves laterally and upward to moist the root zone soil under capillary tensions.

- Pipelines remain filled with water during the period of irrigation

- The upper layers of soil remain relatively dry owing to constant evaporation while lower layers remain moist.

Advantage of sub surface irrigation
• Joint management of irrigation and fertilization
• Simplicity
• Automation
• Production advantage

Disadvantages of Sub surface irrigation
• It requires an economic investment
• High maintenance and high quality water
• Water application pattern must planting pattern

3 Pressurized Irrigation
3.1 Drip irrigation
Drip irrigation is a type of micro-irrigation systems that has the potential to save water and nutrients by allowing water to drip slowly to the roots of plants, either from above the soil surface or buried below the surface. In this system the water is supplied with pressure after filtering it through the pipes with attached hoses designed to supply water in drops. Drip irrigation system distribute water through a network of valves, pipes, tubing and emitters. Depending on how well designed, installed, maintained and operated it is, a drip irrigation systems can be more efficient than other types of irrigation systems such as surface irrigation or sprinkler irrigation.
Advantages:

• Fertilizer and nutrient loss is minimized due to a localized application and reduced leaching.
• Water application efficiency is high if managed correctly.
• Field leveling is not necessary.
• Fields with irregular shapes are easily accommodated.
• Recycled non-potable water can be safely used.
• Moisture within the root zone can be maintained at field capacity.
• Soil type plays a less important role in the frequency of irrigation.
• Soil erosion is lessened.
• Weed growth is lessened.
• Water distribution is highly uniform, controlled by the output of each nozzle.
• Labour cost is less than other irrigation methods.
• Variation in supply can be regulated by regulating the valves and drippers.
• Fertigation can easily be included with minimal waste of fertilizers.
• Foliage remains dry, reducing the risk of disease.

Disadvantages:
• Initial cost can be more than overhead systems.
• The sun can affect the tubes used for drip irrigation, shortening their lifespan.
• The risks of degrading plastic affecting the soil content and food crops. With many types of plastic, when the sun degrades the plastic, causing it to become brittle, the estrogenic chemicals (that is, chemicals replicating female hormones) which would cause the plastic to retain flexibility have been released into the surrounding environment.
• If the water is not properly filtered and the equipment not properly maintained, it can result in clogging or bioclogging.
• For subsurface drip the irrigator cannot see the water that is applied. This may lead to the farmer either applying too much water (low efficiency) or an insufficient amount of water, this is particularly common for those with less experience with drip irrigation.
• Drip irrigation might be unsatisfactory if herbicides or top dressed fertilizers need sprinkler irrigation for activation.
• Drip tape causes extra cleanup costs after harvest. Users need to plan for drip tape winding, disposal, recycling or reuse.
• Waste of water, time and harvest, if not installed properly. These systems require careful study of all the relevant factors like land topography, soil, water, crop and agro- climatic conditions, and suitability of drip irrigation system and its components.
• In lighter soils subsurface drip may be unable to wet the soil surface for germination. Requires careful consideration of the installation depth.
• Most drip systems are designed for high efficiency, meaning little or no leaching fraction. Without sufficient leaching, salts applied with the irrigation water may build up in the root zone, usually at the edge of the wetting pattern. On the other hand, drip irrigation avoids the high capillary potential of traditional surface-applied irrigation, which can draw salt deposits up from deposits below.
• The PVC pipes often suffer from rodent damage, requiring replacement of the entire tube and increasing expenses.
• Drip irrigation systems cannot be used for damage control by night frosts (like in the case of sprinkler irrigation systems)

3.2 Sprinkler irrigation:
This systems is used when water supply is not adequate. The water is pumped with pressure through the sprinkler, attached to pipes and these sprinklers are adjusted in such a manner

to overlap up to one fourth area covered by the other sprinkler. They are then moved to the next point after sufficient percolation has taken place. This is suitable in those areas where the land is undulated or sloppy and the water supply is not regular from the canal.

Advantages:

• Suited to complete range of topographies and field dimensions.
• High irrigation efficiency due to uniform distribution of water.
• Accurate and easy measurement of water applied.
• Land leveling is not essential.
• Soluble fertilizer, herbicides and fungicides can be applied in the irrigation water economically and with little extra equipment.
• More land is available for cropping.
• No interfere with the movement of farm machinery.
• Can be used to protect to crop against high temperature that reduce the quantity and quantity of heaters.
• Easy to operate, operator may be trained quickly.
• Sprinklers are also used to irrigation high valued plantation crops like coffee, cardamom and orchards.

Disadvantages:

• It requires high initial investment.
• Power requirement is usually high since sprinklers operate with more than 0.5 kg/cm2 water pressure.
• Fine textured soils that have low infiltration rate cannot be irrigated efficiently in host windy area.
• Loss of water due to evaporation from the area during irrigation.
• The water must be clean and free of sand, debris and large amounts of dissolve salts.
• Wind distorts sprinklers pattern and cause uneven distribution of water.
• Ripening of soft fruit must be protected from the spray.

3.3 Mist irrigation

This kind of irrigation can be varied in use from agriculture, gardening, and different kinds of farms to crop protection, regulating ambient temperature etc. Mist Sprayers are designed to deliver a fine mist to any plant-life, patio or landscaping your need. They can be mounted to a variety of stakes or mounted onto the mainline tube itself. A variety of different flow rates are available as well as different misting patterns. This aesthetic irrigation method can save precious water, by keeping the water-wastage to a bare minimum.

Misting Irrigation: A very fine mist is emitted from overhead sprinklers, distributing needed moisture ideal for plant propagation and seed germination.

Advantage

1 Fending off plant diseases
2 Minimizing plant stress
3 Increasing growth rates.

Disadvantages

- Higher pressure required to run the system.
- Does not work effectively in open area situations.
- Does not work well in areas subject to air movements.

Simple Techniques for irrigation scheduling

1. Soil-cum-sand miniplot Technique:

In this method one cubic meter pit is dug in the field.About five per cent of sand by volume is added to the dug soil, mixed well and the pit is filled up in the natural order.

2. Sowing high seed rate.

In an elevated area, one square meter plot is selected and crop is grown with four times thicker than normal seed rate.

3. Feel and Apperance Method

Moisture content can be roughly estimated by taking the soil from root zone into the hand and making it into a ball.

ADVANTAGE

The benefit of proper irrigation scheduling include.

• Improved crop yield .
• Improve crop quality.
• Water saving.
• Energy conservation.
• Lower production costs.
• It minimizes water-logging problems by reducing the drainage requirements.
• It assists in controlling root zone salinity problems through controlled leaching.
• It enables the farmer to schedule water rotation among the various fields to minimize crop water stress

DISADVANTAGE.

In practice we find irrigators sometimes fail to practice proper irrigation scheduling . Some of the reasons put forward for this are that;

• If a little water is good, then plenty of water should be even better,
• Benefits of proper irrigation scheduling are not really discernible,
• It is too much of a bother to engage in irrigation scheduling,
• Water is cheap, so there is no need to use it efficiently, and
• Water supply (on rotation) militates against proper irrigation scheduling.

. Irrigation scheduling is the most important in now a days in the agricultural system. Scheduling system that take account of the irrigation need of individual plants and may well involve greater use of plant based system.

Scheduling of irrigation:

- Scheduling of irrigation is a process decides ‘when to irrigate’ and ‘how much to irrigate’ to the crops.

- Most plants are efficient in absorbing water from soil, if the soil moisture level is nearing at field capacity (-0.33 bar).

- Soil indicators, plant indicators, meteorological indicators, combination approach (of soil and meteorological), rough methods for farmers and critical stage approach are some of the means to scheduling irrigation.

- Soil indicators involve in determining moisture content of the soil and finding the deficit level.

- Gravimetric method, feel and appearance method, tensiometer method, electrical resistance method and water budget technique are used as soil indicators.

A crop should be irrigated before it receives a setback in its growth and development. There are following techniques to judge the time of irrigating the crops:

1. On the basis of appearance: When the leaves of plant wilts for sometime at mid afternoon, then it is time to start irrigation. In some crops, leaf curling is noticed in the mid afternoon due to scarcity of water

2. On the basis of soil characteristics: To decide when plants need water, a handful of soil from the zone of greatest root concentration (15-30 cm) should be collected. When to start irrigation to the soil, it depends on various texture as follows:

For sandy loam- on pressing handful of soil, ball will not form and show light color and cracking occurs. For loamy soil- on pressing mudball will form. The ball easily crumbles when tossed in air one foot high and is caught it hand. For clay soil- on pressing mudball will form, the ball cracks open when pressure is applied with thumb.

3. On the basis of available water in soil: When soil moisture content is about halfway between the field capacity and wilting point, it is time to irrigate or to bring soil moisture to field capacity. Scientific methods consists of Gravimetric method; Electrical Conductivity Method and Suction Method

Field capacity:

Field capacity is the moisture content in percentage of soil on oven dry basis when it has been completely saturated and downward movement of excess water has practically ceased

- Such a stage is reached generally 24-72 hours after saturation
- Sandy soils reach field capacity earlier than clayey soils
- Field

capacity is the upper limit of available soil moisture range in soil moisture and plant relations

- The force with which the moisture is held at this point varies from 1/10 to 1/3 to an atmosphere

Wilting point: The WP, also called the permanent wilting point, is the amount of water per unit weight or per unit bulk volume in the soil, expressed in percentage, that is held so tightly by the soil matrix that roots cannot absorb this water and a plant will wilt.

AW= FC-WP

- The PWP occurs at different moisture levels depending on the plant and soil type. Some plants, which are adapted to arid conditions, can survive with very little moisture in the soil. *With most agronomic crops, PWP occurs when the tension in the soil is at 15 bars.* This means that the soil is holding on very tightly to the water in its pores. *In order for plants to use this water, they must create a suction greater than 15 bars.* For most of the commercial crops grown, this is not possible. At 15 bars, most plants begin to die. The difference between field capacity and PWP is called the *plant available water (PAW).*

- Irrigation targets are usually set as a *percent depletion of the PAW*. This depletion level is referred to as Management Allowable Depletion (MAD). The bulk of irrigation research recommends irrigating row crops such as grain or cotton when the MAD approaches *50%*. For vegetable crops, the *MAD is usually set at 40% or less, because they*

are more sensitive to water stress. These deficit amounts assure that water stress will not be so severe as to cause any negative effects, and yet will allow a little "breathing room," in case of a delayed irrigation. Careful monitoring of the PAW needs to be done throughout the season so that the appropriate point of irrigation can be anticipated. The following approaches can be used to determine soil moisture content.

Scheduling of irrigation- IW:CPE

- The use of IW/CPE ratio is suggested as a practical basis of scheduling irrigation.
- The approach is based on the close and direct relationship of crop evapotranspiration with pan evaporation.
- When irrigation is applied, water is lost from the soil through evapotranspiration in the same way as the evaporation occurs from an open pan evaporimeter.
- It is ratio of the amount of irrigation water (IW) applied to cumulative pan evaporation (CPE).
- The pan evaporation values are added up every day till it is equal to certain ratio of the amount of water applied as irrigation.
- The ratio for various crops is determined experimentally by estimating the evapotranspiration by lysimeter studies.
- The IW/CPE ratios for various crops at different agro climatic conditions is determined by research organizations
- In this approach, a known quantity of irrigation water (IW) is applied when cumulative pan evaporation (CPE) reaches a predetermined level.
- The amount of water given in each irrigation ranges from 4 to 6 cm, the most common being 5 cm of irrigation.
- Scheduling irrigation at an IW/CPE ratio of 1.0 with 5 cm of irrigation water is applied when the CPE reaches 5 cm.
- Generally, irrigation is scheduled at 0.75 to 0.8 ratio with 5 cm of irrigation water.
- In IW/CPE ratio approach, irrigation can also be scheduled at fixed level of CPE by varying amount of irrigation water.

Scheduling of irrigation

5. a. By indicator plant:

Some plants show the symptom of wilting very clearly and apparently when water is scarce in soil. These types of plants are called indicator plants. Sunflower is the best example of such plants.

5. b. By sowing at higher seed rates:

One square meter plot is selected at an elevated area
Crop is sown four times thicker than normal seed rate
Plants show wilting symptoms earlier than rest of the crop area (due to high plant density)

Key symptoms: Droping, curling or rolling of leaves and changes in foliage color

6. On the basis of critical growth stages:

Under limited water availability, applying water at critical growth stages. The term critical growth stages is commonly used to define *the stage of growth when plants are most*

sensitive to shortage of water i.e. during these stages if there is shortage of water, *yield is reduced drastically*. This criteria is simple and very practical in crop production.
During shortage of water, it is better to take care of critical stages first to obtain increased water use efficiency.
NOTE: But with irrigating only at critical stages, maximum yield cannot be obtained.

On the basis of critical growth stages:

CROPS	CRITICAL STAGES
Rapeseed and Mustard	Pre-flowering, capsule development
Groundnut	Pegging and Pod formation
Gram	Pre Flowering, Flowering
Pea	Start to flowering , pod formation
Soybean	Early Seedling, flowering and Pod development
Rice	Tillering initiation, Flower primordia formation, flowering
Wheat	CRI stage, Milking Stage
Maize	Silking and Cob Development
Finger millet	Flowering and grain formation

To get optimum yield of wheat grown in loam soil, wheat needs 5 irrigation. At sowing if irrigation is not available, then pre irrigation should be done. After sowing at CRI, later tillering, late jointing stage, flowering and milking stage, irrigation should be given. If farmers don't have sufficient irrigation, then at least irrigation be given at CRI & Milk stage. If 3 irrigations are possible, irrigation be given at CRI, late tillering stage and Milk Stage (research have shown that yield under these 3 irrigation was almost same as that with 6 irrigations)

Crop	Important moisture sensitive stages
Rice, pearl millet, finger millet	Panicle initiation, flowering
Wheat	Crown root initiation, jointing, milking
Sorghum	Seedling, flowering
Maize	Silking, tasselling
Groundnut	Rapid flowering, pegging, early pod formation
Redgram, greengram, blackgram, peas	Flowering, pod formation
Sugarcane	Formative stage
Sesame	Blooming to maturity stage
Sunflower	Two weeks before and after flowering
Safflower	Rosette to flowering
Soybean	Blooming, seed formation

Cotton	Flowering, boll development
Tobacco	Transplanting to full blooming
Chilli	Flowering
Potato	Tuber formation to tuber maturity
Onion	Bulb formation to maturity
Tomato	From commencement of fruit setting
Cabbage	Head formation to firming stage of head
Carrot	Root enlargement

What are the factors to be considered for Scheduling irrigation?

Irrigation scheduling is the process used by irrigation system managers to determine the correct frequency and duration of watering. Out side the growing season a farmers needs to irrigate will depend on several factors.

Factors Influencing Irrigation Scheduling.

Soil, crop and climatic factors influence when to irrigate and how much water to apply, i.e. they influence irrigation scheduling.

Soil: Here the important aspects are soil type and its water holding capacity. There is need to know how much water is available and how much of it can be depleted from the soil without necessarily affecting the crop, hence the talk about MAD.

Root Growth: For a given crop there is need to know, how do, or at what rate do the roots extend deep to tap moisture reserves deep down in the soil profile. Also, what is the nature of the roots of the crop, deep or shallow or whether they are fibrous or just a few. This affects water uptake and hence when to apply more water.

Stage of Crop Growth :Ensuring that crops are not stressed at a particular growth stage is important in crop performance. Some stages of crop growth require that there is sufficient water always and so this affects when to irrigate and how much water to apply. Critical stages vary with crop and growth stage. Examples of critical growth stages include; tasselling and silking in maize, flowering and grain filling in wheat and fruit enlargement in tomatoes. So during these stages water must be readily available to the crop.

Weather Conditions: Atmospheric conditions affect Eto e.g. dry, windy and hot conditions result in high Etc and crops so require more water. Under these conditions irrigation scheduling has to be closely monitored to avoid unnecessary stressing of the crops. Occurrence of rainfall also influence when or not to irrigate.

Drainage:

It is the removal of excess of water (which may be due to heavy rainfall or faulty irrigation) to enhance plant growth development, from the surface or root –zones of cultivated area or from the area to be prepared for cultivation in order to prevent waterlogging.

Importance of Drainage

Ø Drainage reduces soil and nutrients loss from runoff and can help to avoid soil erosion.
Ø Drainage ensures for proper aeration of soil.
Ø Drainage prevents standing crops from choking.
Ø Drainage can help in removal of toxic elements from soil.
Ø Drained water can be collected and used for irrigation in dry periods in future.

Requirements for good drainage-

Ø The maximum duration and frequency of surface ponding
Ø Further supply of water should be checked if the water logging is due to faulty irrigation.
Ø Drainage system should be simple in form.
Ø Drainage system should be self cleansing.
Ø Soil structure should be crumby, spheroidal or granular.
Ø Sandy soil texture can aid to drainage.
Ø Drainage channels or pipes should be leakage proof.
Ø Drains for drainage should be of adequate size with proper sloping forwards.
Ø There should be no any obstacle like vegetation along the drainage channels.
Ø The banks of the drains should not be damaged by flow of water in the drains

Drainage: adverse effect of water logging, requirement

- Causes relatively poor root growth.
- Accumulation of excess soluble salts in shallow water table.
- Reduction of soil strength.
- Oxygen diffusion is 10,000 times lesser than running water.
- Redox potential is – 400 mV.
- Accumulation of CO_2, CH_4, HCO_{3-}, CO_3^{-2} and H_2S.
- Change in the pH and natural stabilization.
- Anaerobic microbes works with low energy level.
- Reduced nutrient availability.
- Accumulation of toxicants (H_2S, CH_4).
- Poor crop growth/nutritional disorders and yield reduction.
- Can impair the N-nutrition of legumes by interfering with nodulation
- Waterlogging injury caused primarily Mn toxicity occurs in plant species with low inherent. Mn tolerance e.g. Lucerne

The most suited drainage system is influenced by:

- soil type
- topography
- rainfall
- outfall type and location.

Type of Drainage

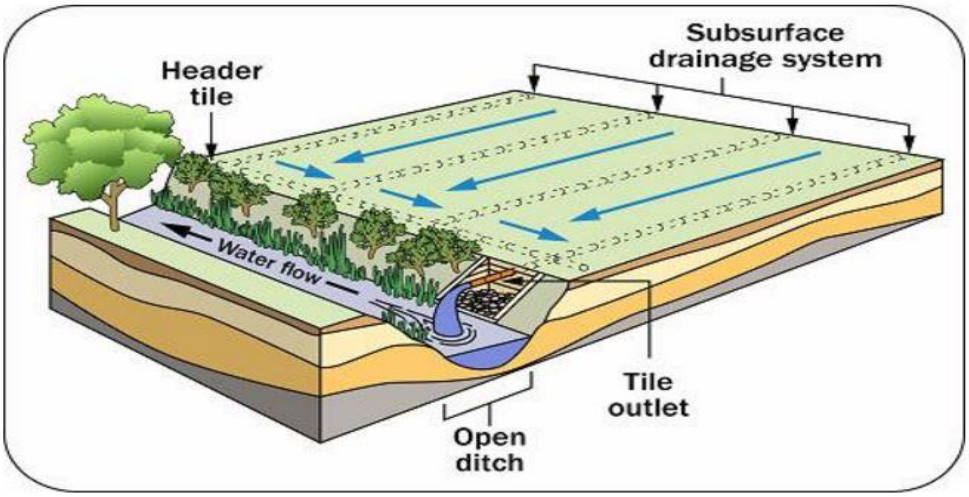
1. Surface Drainage:

- Simplest and most common by digging open drainage at suitable intervals and depths
- In flat areas, >2% land slope
- Is carried out by land shaping

A) Parallel ditch system and field ditch system

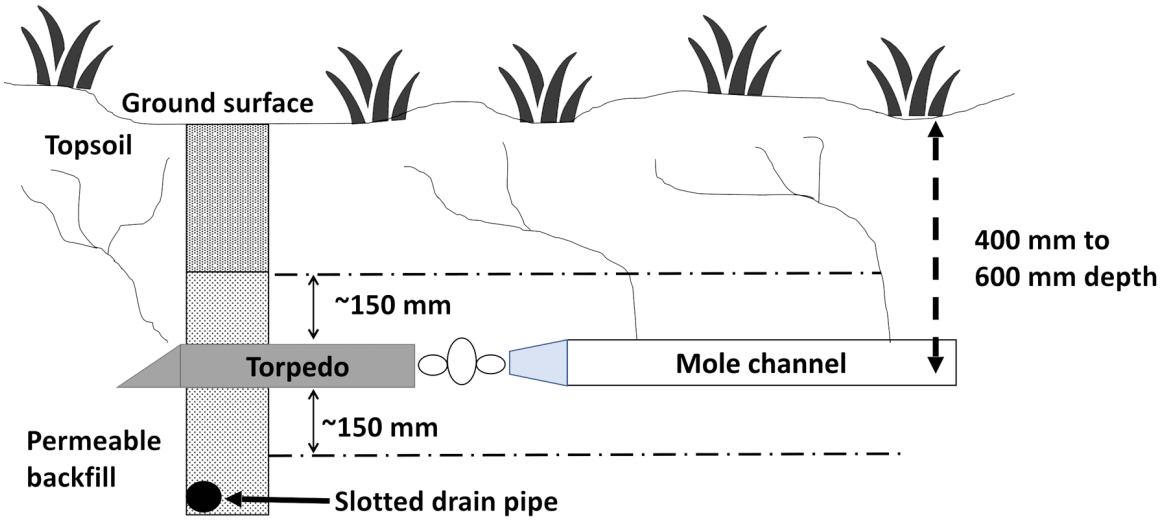
B) Broad bed and Furrow System- Bed width120-150cm, furrow width 45cm and 15 cm raised (Gnut in clay soil)

C) Broad Bed & Furrow Drainage

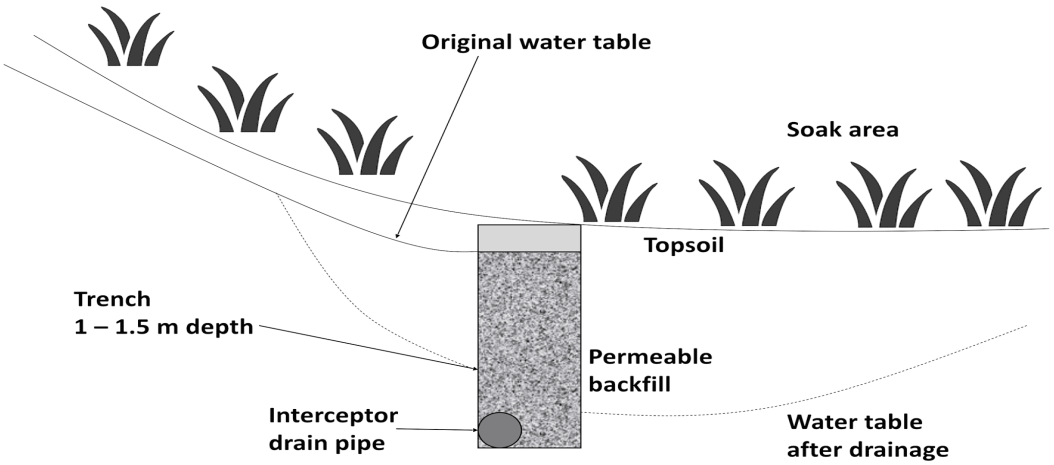


2 Sub surface drainage

a. Mole Drains: Suitable for clay soils, moles are made with mole plough.



b. Intercept drain - These drains are installed at the base of slopes at the change of gradient, usually where a steeper slope meets the flats to intercept the downhill flow of subsurface water. Often the soil type on the slope is more permeable than those of the flats and this forces the water to come to the surface, usually at the change of slope.



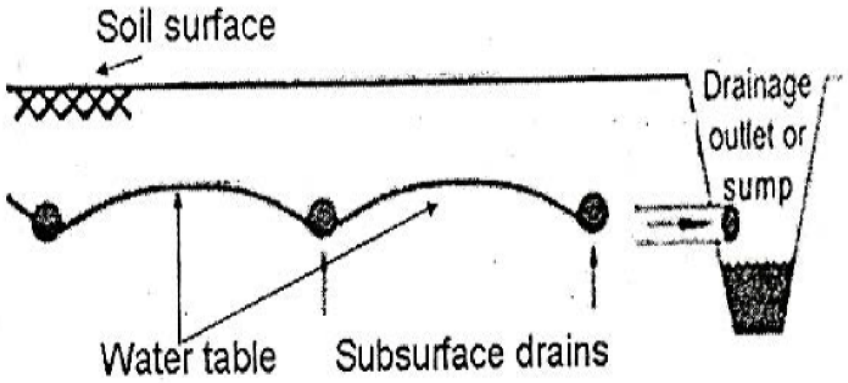
C Backfilling the trenches

Backfill is a major cost of a drainage system but is crucial to the drain's effectiveness so the quality and price of backfill should not be compromised.

In very permeable soils, very little backfill is needed, but in less permeable soils, or where moles are to be pulled through above a pipe, the backfill depth reaches to near the ground surface.

D Subsurface pipes

Subsurface pipes are best suited in deep permeable soils where their depth allows wider spacing and minimises cost. Subsurface pipes can also successfully drain heavy (clay), poorly drained soils but have to be installed so close together that they are uneconomic in extensive farmland systems.



Tile Drains: Is done with <2% slope and includes perforated pipes. It is a practice for removing excess water from the subsurface of soil intended for agriculture. Whereas irrigation is the practice of adding additional water when the soil is naturally too dry, drainage brings soil moisture levels down for optimal crop growth. While surface water can be drained via pumping and/or open ditches, tile drainage is often the best recourse for subsurface water.

Use of Laser Land Level for drainage:

A properly laser leveled farmland or agricultural field promotes even and efficient irrigation. You use less water, the crop grows better and more evenly, and your soil is retained. Laser leveling results in a much more level field because accuracy can be improved by as much as 50% compared with the other systems.

8 Weeds and its managements

Define weed

A weed is any plant that requires some form of action to reduce its effect on the economy, the environment, human health and amenity.

Weeds typically produce large numbers of seeds, assisting their spread and are often excellent at surviving and reproducing in disturbed environments.

A weed can be an exotic species or a native species that colonizes and persists in an ecosystem in which it did not previously exist.

Weeds can inhabit all environments; from our towns and cities through to our oceans, deserts and alpine areas.

Characteristics of weeds

- **Prolific seed production:** Amaranthus spp. – 1, 96, 000 seeds /plant, Chenopodium sp. 72,000 seeds/plant
- **Dormancy in seed:** Chenopodium sp. – 20-25 years, Phalaris minor – 4-5 years
- **Strong root system:** Eg: Cyperus rotundus
- **Competitiveness and Aggressiveness:** High and fast growth rate, having higher leaf area
- **Vegetative propagated:** Propagated by rhizomes, bulbs, tubers, stolen, suckers etc.
- **Morphological similarities:** Phalaris minor in wheat and Echinochloa sp. in rice
- **Deep root system:** Roots of Convolvulus sp. has up to 20 feet deep roots, whereas Cyprus rotundus has 5-7 feet deep.
- **Early seed setting and early maturity**
- **Evasiveness**

Or

- Weeds are extremely noxious, useless and unwanted.
- Weeds are persistent and resistant to control.
- Remain dormant and viable for several years (grassy weeds for 10 years and broad leaved weeds for 50 years).
- Weeds are prolific or having high reproductive capacity.
- Some weeds have very deep roots.
- Some weeds propagated vegetatively.
- Some weed seeds are very similar to crop seeds.
- Weeds have competitive and aggressive habits.
- Dispersal of weed seeds exposes weeds to different ecosystems.
- Weeds are hardy and resist to adverse climatic, soil and disease conditions.
- Weeds are self sown plants.
- Evasiveness of weed because of their better taste, disagreeable odour, and spiny nature and mimicry.

Importance of Weeds

SN	Character	Weed species
1	Maintain Soil Fertility	Typha spp (add 1-35% nitrogen)
2	Control soil erosion	Cynodon dactylon, Convolvulus arvensis
3	Used as fodder	Cichorium intybus, Cynodon spp.
4	Have medicinal value	Leucas aspera is used in snakebite, Striga spp is used in diabetes; Argemone is used in skin disease; Phyllanthus niruri is used in Jaundice

5	Have economical Value	Roots of Cichorium intybus is used in adding flavor to coffee; Cyperus rotundus is used in making agarbatti; Saccharum spontaneum is used in roof making
6	Maintain PH	Argemone maxicana is used for making alkaline soil to acidic; Rumex acetocella is used for making acidic soil to alkaline
7	Used as ornamental plants	Lantana Camera, Eichhornia crassipes
8	Used in Cleaning water :	Eichhornia crassipes;
9	Used as Nematicides	Crotolaria, Parthenium
10	Adds OM to soil	Amaranthus viridis, Convolvulus arvensis
11	Used as Vegetables:	Chenopodium album; Amaranthus viridis;
12	Used for Religious purpose:	Cynodon
13	Useful for cottage industries:	Saccharum spontaneum;
14	Donating genes to crop plants i.e. Saccharum spontanium (used in S.cane breeding)	
15	Used as pollution indicator	Brassica kaber (wild mustard)to indicate NO2 pollution; Stellaria redia (chickweed) to indicate SO2 Pollution

Harmful Effects of Weed

Weeds extend the harmful effects slowly, steadily and inconspicuously and the effect is almost unchangeable.

- If no restriction is imposed they compete with crop plants and the yield reduction of individual crops varies and that of cropping system 5 to 50%.
- Presence of weeds increases the cost of agriculture and hinders the progress of work.
- It increases the irrigation requirement.
- They reduce the value of produce or otherwise adds the cost of cleaning.
- Some weeds when eaten (Cleome viscosa) by milch animals will produce an undesirable odour in the milk. At times death/disorder/disformity may occur. eg: *Datura stramarium*
- The fruits and seeds of *Xanthium strumarium* and *Achyranthes aspera* entangle with wool which fetch lower prices.
- They harbour insect pests, pathogen and parasites
- They reduce the value of the land
- Presence of weeds will impair the purity of varieties by chance of cross pollination

- Weeds cause health hazards to man and animals
- Weeds cause allelopathic effect

Losses due to weeds

- 30% insects; 45% weed loss; 5% others; 20% diseases
- Yield loss could be Rice:30-35%; Wheat:15-30%; 18-85% Maize
- ⇧ Agricultural cost 50% tillage is done for controlling weeds
- ⇧ Inter cultivation, harvesting, threshing, cleaning cost in +nce of weed
- Loss of quality of plots/ produce/ food with objectionable weed
- Harbors insect-pests, pathogens and parasites
- Loss in animal health as well as their produce
- Impair the purity of variety
- ⇧ cost for repair and maintenance of highways, railways, electric lines
- Weed control operations may damage root and crop damage
- Restricts drainage, increases cost of irrigation
- Interfare in pisciculture and cultivation of aquatic crops
- Impair recreation of water bodies and navigation of water ways

Classification of weeds

1. Classification on the basis of life cycle (ontogeny)

A) **Annual weeds -** grow and flower in one year. Some weeds in orchards are winter annuals, i.e. they begin their growth in the fall, forming a rosette, and flower the following spring or summer. Propagates by seed

B) **Biennial weeds -** have a two-year life cycle, producing leaves in the first year and flowering in the second year.
Annual and biennial weeds compete for nutrients and water as they grow under trees. After they flower, they die. However, their seeds may cause recurring problems for several years by forming a soil seed bank. Propagates by seeds, vegetative part or by both

C) **Perennial weeds** - live for many years, and generally establish from various types of root systems, and many also spread by seeds. They usually flower every year, expanding their root system and spreading by both methods through orchards. Perennial weeds can be very competitive, especially if they grow in thick patches.

2. A/o leaf size:
a.Dicot*: Bethe, lude,*
b. Monocot: **Anagallis arvensis**
c. Sedges*: Cyperus spp*
d. Filamentous: **Swine Cress**

3. A/o Nature of Stem

a. Woody Erect or Strong: Chutro, bayar, lantana
b. Weak: Oxalis spp

4. A/o habitat

A Terrestrial: Solanum nigrum
B **Aquatic: Pistia spp**

5. A/o Associaton

a. Season bound weed: Summer perennial and winter perennial

b. Crop bound weeds: Parasitize the host crop, depend for their survival on host plants for nutrition. Eg: Orobanchae spp. in rapeseed & mustard; Striga spp. In maize; viscum spp. in apple, cherry, cuscuta spp. in cotton, tobacco, potato

c. Crop associated weeds:

Rice associated weeds: *E. colonum; E. crusgalli*
Maize associated weeds*: P. minor, A.fatuwa,*
Black gram associated weeds: *Solanum nigrum*

6. A/o Origin

A) Alien Weeds (Foreign origin): Quarantine strong

B) Native Weeds (Indigenous to country): Biological control useful

7. A/o Plant family

a. Poaceae:
b. Asteraceae
c. Euphorbiaceae
d. Fabaceae
e. Chenopodiaceae
f. Convolvulaceae
g. Amaranthaceae
h. Tiliaceae

8. A/o Dependency on host

a. Total Parasitic weeds: Amarbel in lucern (Cuscuta)

b. Semi Parasitic weeds: Striga in Sugarcane, Orobanchae in tobacco, Loranthus in Mango

c. Independent weeds: Argemone, Convolvulus, Cyperus rotundus

9. A/o Growth Characteristics

a. Erect: Chill, Spenochea zeylanica
b. Prostrate: Oxalis corniculata
c. Twinning: Amarbel
d. Trailing: Convolvulus arvensis
e. Runner: Sedges
f. Procumbent: Tridax procumbens
g. Diffuse: Bochrharia diffusa

10. A/o Soil type

A. Soil Texture: a. Coarse/gravel b. Sandy weeds; c. Clay weeds
B. Soil Reaction: a. Acidophytes; b. Basophytes; c. Neutrophiles
C. Soil Fertility: a. High fertile soil weeds b. Low fertile soil weeds:

Goals of weed management

The goal in managing weeds is to suppress weed crop competition during critical periods of crop development. It is important to understand these facts about the critical weed-free period:

- If the crop is kept weed-free for the critical weed-free period, no yield reduction occurs
- Weeds emerging after the critical weed-free period do not affect yield significantly
- When weeds compete with trees during the critical weed-free period (especially during the planting year), effects may last several years, and possibly for the life of the orchard
- There are other valid reasons to control weeds outside of these critical periods such as attractiveness for pick-your-own customers, harvest efficiency and reduction of weed seed banks. However, controlling weeds outside of the critical weed-free period does not increase yields.

Integrated Weed Management considers all these weed control methods

- Preventive measures
- Physical
- Chemical
- Biological
- Cultural

1 Preventive measure

- Prevention is the *most effective method* of dealing with weeds
- Once a weed has entered an area and become established, eradication is far more expensive and it is likely that greater resources will be required to control its further spread and reduce its impact.
- In agriculture, the pathways for spread include *transported livestock* and *fodder, contaminated crop and pasture seeds*, *deliberate introductions of new species*, and *contaminated machinery* such as *harvesters and recreational vehicles (including boats which can spread water weeds).*

1. Restricting the opportunity for new weeds to invade and spread:

- Be vigilant about introducing stock, fodder or seed onto your property to ensure weeds will not be introduced.
- When buying stock, find out where the stock has come from and what weeds infest that area.

Buy certified weed free fodder and seed where possible.

- Restrict the movement of vehicles and machinery on your property in periods when seeds are likely to spread.
- Establish tracks and laneways along which vehicle movement can be concentrated.
- Wash down vehicles which have been in known infested areas.
- Do not allow machinery or vehicles to enter your property unless they are clean.

2. Restricting the spread of existing weed infestations:

- Carry out control works prior to other works.
- Slash and cultivate when weeds are outside of seeding period.
- Work the clean area first and the infested area last. Work from the outside in and clean down equipment prior to moving into a clean area.

3. Quarantine:

- Hold livestock that may be infested with seed in a single location until they are shorn or until weed seeds have had the chance to pass through their digestive system.
- Feed out infested fodder in a feed lot type situation only and introduce clean fodder to stock.

4. Monitor:

- Continually monitor weed infestations and carry out control works.

2 **Physical methods of weed control**

Physical control is the removal of weeds by physical/ mechanical means

Mowing, Grazing, Mulching, Tilling, Burning

Depends on the area of weeds to be managed, what the land is used for, physical characteristics and the value of the land

Machinery, vehicles, tools and footwear, is cleaned free of weed seed before moving, to stop the spread of weeds to new areas

Burning removes the above-soil body of the weeds killing most of the plants

If carried out before seed is set it can prevent the further spread of weeds. Burning can be undertaken over a wide area with minimal human input. As with tilling, burning exposes the soil surface to erosion. If burning is used as a control method, caution should be exercised to minimize the risk of harm to the environment and to those undertaking the activity.

Mulching, by covering the ground with a layer of organic material, suppresses or kills weeds by providing a barrier between the weeds and sunlight. Mulching has an added advantage in that it improves the condition and moisture level in the soil. Planting competitive and desirable plants that provide a dense cover over the weeds suppresses weed growth in a similar way to mulching.

Hay making, mowing and grazing before weeds produce seeds restrict the amount of weed seed in an area and reduce the spread of weeds.

Hand Removal/weeding:

Removal of weeds by hand, including hoeing, and is a good method for selective removal of weeds without disturbing the surrounding desirable vegetation.

Is labour- intensive and is often only used in small areas, such as gardens or in larger areas during bush regeneration.

Tilling, the ploughing or cultivation method that turns over the soil, buries the weed beneath the soil

Provides a barrier to the sun, therefore killing the weeds

Tilling is a form of physical control that can be easily undertaken over a wide area, using agricultural machinery. This method is useful for making soil ready for planting new crops,

but it can lead to damage in soil structure and exposes the soil to erosion and further invasion by weeds.

Digging/Hoeing

3 **Cultural methods of weed control (GAPs)**
Encourage the competitiveness of desired species that are more competitive and fast growing. This suppresses weed growth by reducing access to available sunlight, nutrients and moisture and can include:

- Choose plant and crop species or cultivars that are naturally more competitive. This can include using plant species that suppress other plant species by the release of toxins.
- Use high quality (large and plump) seeds, as they are more likely to produce vigorous and competitive plants.
- Use increased seeding rates and narrow row spacing.
- Use shallow seeding techniques, where possible, to allow the desired species to grow above the soil surface more quickly.
- Ensure the desired plant is placed in the optimum growing environment.
- Use fertilizers in the optimal growth period to encourage rapid growth of the desired species.
- If possible use plant species that are native to the local environment.
- Using different land management routines year after year may result in weeds adapting to these practices. Some practices that make it hard for weeds to adapt are:
- Crop Rotation: if a weed has adapted to grain crops continuously being sown, then alternating with a broadleaf crop will remove the environmental condition to which the weed has adapted.
- Rotate species with different seasonal and growing cycles.
- Rotate herbicides with different modes of action to help delay the development of herbicide resistance.
- Intercropping suppresses weeds better than sole cropping. Short duration pulses (grams and soybean) effectively smoother weeds without reducing the yield of main crop
- Water stagnation and puddling in rice
- Summer tillage is done to check population of perennial weeds. Soil heaving during the month of April, May and June expose weeds, roots, rhizomes and tubers of perennial weeds
- Minimum tillage is very useful in reducing early growth of weeds
- Irrigation and drainage

4 **Biological methods of weed control**
The biological control approach makes use of the invasive plant's naturally occurring enemies, to help reduce its impact

It aims to reunite weeds with their natural enemies and achieve sustainable weed control.

These natural enemies of weeds are often referred to as biological control agents.

An early success in biological control of weeds in Australia was the use in the 1920s of the Cactoblastis Moth (*Cactoblastis cactorum*) to control Prickly Pear (*Opuntia stricta*), which at the time was smothering large tracts of north-east Australia, and spreading rapidly each year.

The larvae of the Cactoblastis Moth eat the leaves and seed pods of the Prickly Pear. *The release and spread of Cactoblastis Moth in Australia virtually destroyed Prickly Pear populations*

Goats/Sheep: controlling ragwort

Biological Agents	Weeds
Leaf Beetles (Octotoma scabripennis)	Lantana camara
Leaf mining chrysomelids (Uroplata giraldi)	Lantena camara
Scale Insect (Dactylopius tomentosus; Pyralid moth (Cactoblastis cactorum)	Prickly pear cactus (Opuntia intermis)
Flea beetle (Agasicles hygrophyla)	Alligator weed (Alternanthera philoxeroide)
Common Carp/Chinese carp fish	Aquatic weeds
Leaf beetles	Parthenium hysterophorus
Tilapia sp.	Eichhornia crissipes (water hyacinth)
Sheep/Goat	Tansy ragwort
Rhizocctinia blight (Fungi)	Hyacinth
Snails	Submerged weeds like coontail and algae
Mites (tetranychus sp)	Prickly pear
Cowpea as intercrop in sorghum	Effectively reduces the growth of weeds in sorghum
Althesapaecuta cyperi (stem boring weevi); Bactra minima (stem borer)	Cyperus rotundus

ADVANTAGES

- Biological control can be cost effective in long run
- A high degree of specificity of weed
- No effect on non-target and beneficial plants or human
- Absence of residue build up in the environment
- Effectiveness for managing herbicide resistant weed population

DISADVANTAGES

- Slow process (Lot of time and patience for the biological agent, as their population should increase)
- Difficult for biological agent to establish in the system
- Proper planning for specific weed is needed

5 **Chemical methods of weed control**

A herbicide is a chemical that affects plants. Although there are a large variety of herbicides available they function in a limited number of ways, known as modes of action. These modes of action determine how the herbicide controls weeds:

- by speeding up, stopping or changing the plant's normal growth patterns;
- by desiccating (drying out) the leaves or stems; Glyphosate, Paraquat, Diquat
- by defoliating the plant (making it drop its leaves); 2,4-Dichlorophenoxyacetic acid (2,4-D) and 2,4,5-Trichlorophenoxyacetic acid (2,4,5-T). 2,4-D and 2,4,5-T are absorbed by broad-leafed plants, killing them by causing excessive hormonal growth

The well-known herbicide glyphosate, for example, prevents the target plant making key amino acids. As well as using different modes of action, herbicides can be classified according to how they are taken up by the plant. The main types are:

- Contact - these kill plant tissue at or near the point of contact with the herbicide (they do not spread around the plant). Therefore, they require even coverage in their application.
- Systemic - these move through the plant tissues via the plant's circulation system, and can be injected into the plant.
- Residual - these can be applied to the soil in order to kill weeds by root/shoot uptake. They remain active in the ground for a certain length of time, and can control germinating seedlings.

Herbicides also have differing selectivities, and can be categorised as either broad spectrum (working on a wide variety of plants) or selective (working on a specific range of plants). For example some herbicides are effective on grasses, whereas others are more effective on woody weeds and will leave grasses intact to provide competition against re-establishment of the weeds.

Pre emergence: Pendimethylene, S-Metolochlor,

Post emergence: Atrazine, clodinofop and pinoxaden, Isoproturon and and sulfosulfuron

ADVANTAGES

- Reduces early weed competition in crops thus increasing yield
- Reducing labor requirements for weeding
- Pre-emergence and post-emergence herbicides enhance timely weeding
- Makes it possible for a farmer to cultivate larger hectare with efficient weed control
- Quick, Efficient and Cost effective

DISADVANTAGES

- Environment pollution
- Perennial weeds are generally not controlled
- Less effective under dry or cold soil conditions
- Residue may restrict crop rotation the next year

Integrated Weed Management Measures:

1. Preventative Weed Control: Preventative weed control refers to any control method that aims to prevent weeds from being established in a cultivated crop, a pasture, or a greenhouse. Examples of preventative weed control would be using certified weed free seed, only transporting hay that is weed free, making sure farm equipment is cleaned before moving from one location to another, and screening irrigation water to prevent weed seeds from traveling along irrigation ditches.

2. Cultural Weed Control: Cultural weed control refers to any technique that involves maintaining field conditions such that weeds are less likely to become established and/or increase in number. Examples of cultural weed control would be crop rotation, avoiding overgrazing of pastures or rangeland, using well-adapted competitive forage species, and maintaining good soil fertility.

3. Mechanical: Mechanical weed control refers to any technique that involves the use of farm equipment to control weeds. The two mechanical control techniques most often used are tillage and mowing.

4. Biological: Biological weed control refers to any technique that involves the use of natural enemies of weed plants to control the germination of weed seeds or the spread of established plants. This is a rapidly expanding area of weed control with many examples. Examples of biological weed control include sheep to control tansy ragwort or leafy spurge, cinnabar moth and the tansy flea beetle to control tansy ragwort, the chrysolira beetle to control St. John's Wort, and the use of goats to control brush on rangeland.

5. Chemical: Chemical weed control refers to any technique that involves the application of a chemical (herbicide) to weeds or soil to control the germination or growth of the weed species. In economic terms, chemical control of weeds is a very large industry and there are scores of examples of chemical weed control products. Common examples of chemicals used to control weeds in forages are 2,4-DB; EPTC; bromoxynil; and paraquat.

TOOL	ADVANTAGES	DISADVANTAGES
CULTIVATION/HOEING	- effective, especially on small weeds - non-selective - controls all emerged growth - equipment readily available	-may damage soil structure - may spread perennial weeds - may damage trees/roots - provides only short-term control
MUL-CHING	-effective if properly managed - non-selective - suppresses all emerging weeds - holds soil moisture as well - provides long-term control	- availability of mulch - cost of mulch/application - attractive to rodents - may affect tree nutrition - must be free of weed seeds

MOWING	-rescue treatment - quick suppression - equipment available - reduce seed spread	- weeds may still compete - quick regrowth - several mowings required - may damage young trees
HERBICIDES	-effective - easy to apply - can be selective - timely	- require 2% soil organic matter - directed spray equipment - effects on pest complex - cost varies
BURN DOWN	-controls all emerged weeds - inexpensive - widely available - can target critical weed-free period	- may damage trees if absorbed (systemic) - early weeds compete with trees - perennial weeds are not killed - new seedlings germinate after application
SELECT-IVE	- can target critical weed-free period - targets specific weeds - minimizes herbicide use - generally safe for trees	- does not control a broad spectrum of weeds - often an extra application - additional expense - timing is critical
SOIL RES-IDUAL	-reliable control - effective for longer periods - can target critical weed-free period - cost effective - broad spectrum - longer window to apply	- may cause tree injury - not safe on low organic matter soil - may have tree-age restriction - may leave residues after orchard removal - may require incorporation - applied before weed problems are known - may affect soil biology

How Are Weeds Spread?

Weeds reproduce and spread by many methods and may have special adaptions to assist their dispersal. These include seeds, spores, runners and separated root and shoot fragments. Nature plays a big part in spreading weeds over small distances in wind and water. Humans, unfortunately, are by far the worst offenders at spreading weeds, particularly on dirty tools, machinery, vehicles, clothing and transported animals. Some of the more common methods of weed spread and methods used to prevent this are discussed as follows:

1 Stock Feed – Contamination of hay and grains with wet seeds is one of the most common means by which weeds are spread. Feeding animals in a confined area or in one paddock reduces the risk of weeds invading the rest of the property.

2 Stock - Weed seeds ingested by stock can remain viable after passing through the digestive tract. New stock should therefore be confined to one paddock for a week after arrival. This allows time for any viable seeds that have been ingested by the stock to be expelled. Seeds which are sticky or spiny can spread on the animals, for example in sheep fleece.
3 Machinery - After using machinery in weed-infested areas ensure they are thoroughly cleaned. Weed seed can be transported in tyres and in other road materials.
4 Soil Disturbance - Minimise the amount of soil and vegetation disturbance when carrying out work. Disturbed ground creates an ideal seed bed for both existing and introduced weed seeds to germinate.
5 Humans And Animals – Check your own clothing, socks, cuffs, jumpers, boots etc. after walking through weed-infested areas. Remove and destroy and seeds you find. Dogs and cats can also disturb seeds in their coats, as can wild animals, particularly vermin such as foxes and rabbits. Birds also transport seeds when they feed on wet fruits and seeds such as blackberry and cotoneaster.
6 Garden Escapees – Many weeds were introduced to Australia as ornamental plants or for herbal medicine, which have since "escaped" from our gardens and become wild. For example – pampas grass, broom, Spanish heath and cotoneaster. It is best to avoid "weedy" species when choosing plants for your garden.
7 Water And Wind – Wet seeds entering waterways or drains can be spread to new areas downstream. On windy days when plants are seeding, the wind can easily disperse the seed quite some distance. Many weed species have seeds especially adapted to be carried by the wind.
8 Explosive Projection – Many weeds such as gorse disperse their seeds through explosive projection. The seeds are encased in pods, which can be thrown up to several metres from the parent bush.

9 CROPPING SYSTEM

Farming system
SYSTEM APPROACH: A system is defined as a set of elements or components that are inter related & interacting among themselves.

Farming systems = appropriate combination of farm enterprises viz. (cropping system, livestock, poultry, fisheries, forestry, bee keeping, sericulture) and the means available to the farmer to raise them for increasing profitability.

All these interact adequately with environment without dislocating the *ecological & socio-economic balance* to meet the national goals

Farm resources – Land, Labor, Water, Capital & Infrastructure

Farm enterprises – Dairying, Poultry, Honey bee keeping, Sericulture, Lac culture, Piggery, Sheep & Goat raising, Fishery.

CROPPING PATTERN

Cropping pattern refers to *proportion of area* under different crops at different points of time.

Cropping pattern also indicates the time and spatial arrangement or sequence of crops and or fallow in a particular land area

Thus, any change in cropping pattern would indicate:

1 Change in proportion of land under different crops
2 Change in time and space sequence of the crops.

Monocropping: If the land is occupied by one crop during one season, the cropping pattern is monocropping. [Space sequence]

Monoculture: If the land is occupied by one crop during one season and next season and next to next season (same crop grown year after year), the cropping pattern is called monoculture (Time sequence)

Multiple Cropping: If more than one crop are grown in succession within a year on a field, it's called multiple cropping.

If these are two crops, its called double cropping.

C**ropping System = Cropping pattern +Management**

CROPPING PATTERN: Crop rotation practiced by a majority of the farmers in a given area of locality, is cropping pattern. It is also *the proportion of area* under various crops at a point of time in a unit area.

It indicates yearly sequence and spatial arrangement of crops & fallow in an area.

CROPPING SCHEME: Information about area, estimated production and losses in soil fertility according to crop before sowing crops, is called cropping scheme.

CROPPING SYSTEM: Principles and practices of crop production and their interactions with farm resource technology and environment.

Cropping system represents crop's patterns used on farm & their interactions with farm resources, other farm enterprises and available technology which determine their makeup.

Cropping system comprises all components required for the production of a particular crop and the interrelationships between them and environment (TAC, CGIA R, 1978). In other words, a cropping system usually refers to a combination of crops in time and space. Combination in time occurs when crops occupy different growing period and combinations in space occur when crops are inter planted. When annual crops are considered, a cropping system usually means the combination of crops within a given year (Willey et al.,1989).

Types of cropping systems:

Monocropping/ monoculture: It refers to growing of only one crop on apiece of land year after year. It may be due to climatologically, socio-economic conditions or due to specialization of a farmer in growing a particular crop.

Multiple cropping : Growing two or more crops on the same piece of land in one calendar year is known as multiple crops.

Sequential Cropping is growing of two or more crops in sequence on the same piece of land in a farming year. On the basis of number of crops in a year, it is called *double, triple or quadruple cropping*. Examples of double cropping are Rice-Potato; Rice-Mustard; Examples of triple sequential cropping include Rice-Potato-Groundnut.

Monoculture

The cultivation or growth of a single crop or organism especially on agricultural or forest land. The practice of growing the same crop each year on a given acreage is monoculture.

Advantages of Monoculture

- It may permit each crop to be grown on the soil best suited to it, if different kinds of soil exist on the farm.
- Fertility level of the soil can be adjusted to fit one crop more precisely than it can be adjusted to fit all the crops in a rotation.
- Systems based on monoculture usually offer greater flexibility in planning the system to meet year to year changes in the need for various crops. Part of the acreage can be shifted from one crop to another without upsetting the total farm cropping plan.

Disadvantages of Monoculture

- The entire nitrogen need of non-legume crops must be met by purchased fertilizers or by use of manure
- Closer attention to soil erosion is necessary, except for perennial crops
- Soil-structure problems can become severe where inter tilled crops are grown continuously
- Farmer should completely depend on chemical insecticides, disease-resistant plant varieties, soil fumigation, and similar methods of controlling insects and diseases that could be controlled by crop rotation.

Intercropping

Inter cropping: It is growing of two or more crops simultaneously on the same piece of land with a definite row pattern. Example of intercropping is planting alternating rows of maize and beans, or growing a cover crop in between the cereal rows. Based on the percent of plant population used for each crop in inter crop's system, it is divided into two types viz. additive series and replacement series.

Main objective of intercropping is higher productivity/unit area in addition to stability in production. It utilizes resources efficiently & their productivity is increased.

For successful intercropping there are certain important requirements:

- The time of peak nutrient demands of component crops should not overlap.
- Competition for light should be minimum among the component crops.
- *Complementary relationship* should exist between the component crops.
- The difference in maturity of component crops should be at least 30 days.

Advantages of intercropping

- It increases productivity per unit area
- Seeds of the crops can be sown and harvested separately at suitable timings

- Two or more crops having different ripening periods can be used for inter cropping
- Specific fertilizers required by different crops can be applied easily
- Specific pesticides, weedicides for different crops can also be used for individual crop
- Produces of each crop can be marketed and consumed separately

Mixed Cropping

Mixed cropping: It is growing of two or more crops simultaneously intermingled without any row pattern. It is a common practice that the seeds of different crops are mixed in certain proportion and are sown E.g.: Wheat + Mustard; Wheat+Pea

Advantages of mixed cropping

1. The nitrogen fixing bacteria in the root nodules of leguminous crop increase the soil fertility by the conversion of atmospheric nitrogen into nitrogenous nutrients
2. Difference in requirements by growing crops will minimize crop failure. If one crop is destroyed by the shortage of nutrients or water, the other might still yield a good harvest
3. If two kinds are grown together, the presence of one crop discourages the growth of other plants esp. weeds
4. It is economically beneficial because the farmers produces more than one crop which helps him earn more
5. Due to complementary effect of component crop, yield of both crops will increase. Legumes have beneficial effect on cereals and non-legumes

Multistoried Cropping (Multi-layer or multi-tier)

- Is one kind of intercropping in which plants of different height are grown in the same field at the same time.
- Is mostly practiced in orchards and plantation crops for maximum use of solar energy even under high planting density. (Crops of varying heights, rooting pattern and duration).
- The key objective is to utilize vertical space more effectively. Examples: Mango+Guava+cowpea; Coconut+blackpepper+cacao+pineapple, Coconut+coffee+papaya+pineapple, Coconut+papaya+Pineapple, Mango+pasture, Pigeonpea+sesame+groundnut, Maize+greengram+groundnut, Spinach+radish+onion, Sugarcane+potato+onion(seed), benefits of Multistoried Cropping (Multi-layer or multi-tier)
- Income per unit area increase substantially as the system minimize risks of crop yield loss.
- This system enables a steady supply of farm products the whole round the year
- Helps to maximize land use by allowing each crop to utilize soil moisture at different depth of soil and catch solar energy at different heights
- Helps in effective control of weeds
- Maintains ecological balance, increases biodiversity
- Utilizes leaching materials more effectively

- Reduces the impacts of hazards like high intensity rainfall, soil erosion and landslides.

Relay cropping:
It refers to planting of succeeding crop before harvesting the preceding crop like a relay race where a crop hands over the land to next crop in quick succession.

The ***seeding of one crop into another standing crop***, e.g., soybean and wheat (during the harvest of wheat, soybean is at flowering stage). It is a practice of starting one crop in another. Here, ***second crop is planted even before the first crop is harvested*****.** Thus, both crops share some part of the season. Relay cropping is essentially a special version of double cropping, where the second crop is planted into the first crop before harvest, rather than waiting until after harvest as in true double-cropping. In this way, **both crops share a portion of the growing season,** increasing solar radiation and heat available to each. Relay cropping beans between rows of maize helps to fertilize the maize, they can be planted before the maize is harvested. Plant them two to a hill and 25 cm apart.

Advantages:
- Less risk since yields do not depend on one crop alone.
- Better distribution of labor.
- Some diseases and insects appear to spread less rapidly under intercropping.
- Better erosion control due to better ground cover.
- Any legumes involved may add some nitrogen to the soil and this increase carbon sequestration.

Disadvantages:
- Mechanization is difficult.
- Management requirements are higher.
- Overall costs per unit of production may be higher due to reduced efficiency in planting, weeding and harvesting.

Advantages of multiple cropping
- Multiple cropping is a form of Ecological Intensification and is the system when two or more crops are grown at the same time or in a sequence.

- It does this by balancing three key ecological processes: competition, on the one hand, and commensalism (one plant gaining benefits from the other) or mutualism (both plants benefitting each other) on the other.

- Typically, farmers will plant crops as close together as possible to utilize all the available land. When different crop species or varieties are grown together, the competition may be fierce; trees grown in a maize field, for example, may shade out the crop. But this can be compensated for by determining the optimal spacing and by exploiting various forms of commensalism or mutualism, for example where the tree may be a legume, providing nitrogen for the crop plant beneath.
- Increases Biodiversity
- Provides habitat for variety of insects & soil organisms
- May increase no. and diversity of natural predators
- Kiri ko tirimiri

- Growing highly nutritious & diverse crops can increase amt of nutrients a household receives (home/kitchen garden)
- Acts as insurance against crop failure in abnormal weather conditions
- Different crops grown together reduces or dilute the chance of pest infestation/loss
- Multiple cropping with cash crop (having high demand) increases income

Requirements of multiple cropping

- Nutrient demands: The two crops cannot require the same amount of nutrients. It is better to restore certain nutrients needed by the other
- Water requirements: Both crops do not require the same quantity of water. If one need more water, the other crop must need less.
- Duration: A long duration crop is grown with a short duration crop
- Root Growth: If one crop has roots which do not penetrate deep into the soil, the other must have deep penetrating roots
- Size: To minimize competition of light, the two should have different crop canopy. One should be short and other long

The physical requirements of multiple cropping are:

- Well-developed irrigation system.
- Continuous supply of electricity.
- Availability of tube wells.
- Usage of modern agricultural forming tools and machinery.
- Implementation of modern farming practices and techniques.
- Availability of manpower.

Factors affecting multiple cropping

- The factors are: 1. Biological and Physical Aspects 2. Soils 3. Crop Varieties 4. Water Control 5. Fertilizer Needs and Multiple Cropping 6. Insect, Diseases and Weed Control 7. Post-Harvest Technology 8. Cropping Sequences and Yields 9. Timing 10. Social and Economic Aspects of Multiple Cropping and a Few Others.
- Other factors that may Influence Favorably or Unfavorably the Adoption of Multiple Cropping:
- These may be:
- (i) Economic reasons.
- (ii) Prospects which demand policy issues.
- (iii) Certain policy issues having subjectivity of the farmers.
- (iv) Social considerations.
- (v) Ecological considerations.

Crop Rotation

Crop Rotation means recurrent succession of crops on the same piece of land either in a year or over a longer period of time.

It is a process of growing different crops in succession on a piece of land in a specific period of time, with an objective to get maximum profit from least investment without impairing the soil fertility.

It is the practice of growing different crops alternately in the same field or soil. It is used for increasing productivity, maintaining fertility and moisture content of the soil.

Principles/characteristics of Crop rotation:

1 It should be adaptable to the existing soil, climatic and economic factors.
2 The sequence of cropping adopted for any specific area should be based on proper land utilization. It should be so arranged in relation to the fields on the farm that the yields can be maintained and soil losses through erosion reduced to the minimum.
3 The rotation should contain a sufficient acreage of soil improving crops to maintain and also build up the OM content of the soil.
4 In areas where legumes can be successfully grown, the rotation should provide for a sufficient acreage of legumes to maintain the N supply of the soil. The rotation should provide roughage and pasturage for the livestock kept on farm.
5 It should be so arranged as to help in the control of weeds, plant disease & insect-pests.
6 It should provide for the acreage of the most profitable cash crops adapted to the area.
7 The rotation should be arranged as to make for economy in production & labour utilization exhaustive (potato, sugarcane) followed by less exhaustive crops (oilseeds & pulses)
8 The crops with tap roots should be followed by those which have fibrous root system. This helps in proper & uniform use of nutrients from the soil & roots do not compete with each other for uptake of nutrients. The selection of crops should be problem and need/demand base:
i) According to *need* of people of the area & family.
ii) On slop lands alternate cropping of erosion promoting and erosion resisting crops should be adopted.
iii) Under Dryland or limited irrigation, drought tolerant crops (Gahat) in low lying & flood prone areas, water stagnation tolerant crops (Paddy, Jute) should be adopted.
iv) Crops should suit to the farmer's financial conditions, soil & climatic conditions.

Advantages of Crop Rotation

1. There is an overall increase in the yield of crops due to maintenance of proper physical condition of the soil and its OM content.
2. Inclusion of crops having different feeding zones and different nutrient requirements help in maintaining a better balance of nutrients in the soil.
3. Diversification of crops reduces the risk of financial loss from unfavorable weather conditions and damage due to pests & diseases.
4. It facilitates more even distribution of labour.
5. There is regular flow of income over the year.
6. The incidence of weeds, pests and diseases is reduced and can be kept under control.
7. Proper choice of crops in rotation helps to prevent soil erosion.
8. It supplies various needs of farmer & the livestock.
9. Agricultural operations can be done timely for all the crops because of less competition.

Intercropping

Intercropping is different from crop rotation because two or more crops are grown one after other. On the basis of spatial arrangement, the intercropping can be of different types such as:

Row intercropping: When cropping involves the component crops arranged in alternative rows. The benefit of this include optimum utilization of land, space and suppression of weeds during the juvenile stage of the main crop.

Strip intercropping: When cropping involves growing of two or more crops in strips that are wide enough to allow separate management of the two crops; but close enough for the crops to interact.

Mixed Intercropping: Growing of two or more crops at the same time with no distinct row arrangement.

Relay intercropping or relay cropping: System in which a second crop is planted when an existing crop has just flowered but before harvesting. Thus relay cropping has minimal temporal overlap of two or more crops.

Cropping intensity

Cropping intensity: Number of crops cultivated in a piece of land per annum is cropping intensity.

[Cropping intensity = (Gross cropped area / Net sown area) x 100]

Net Area Sown: This represents the total area sown with crops and orchards. Area sown more than once in the same year is counted only once.

Gross Cropped Area: This represents the total area sown once and/or more than once in a particular year, i.e. the area is counted as many times as there are sowings in a year. This total area is also known as total cropped area or total area sown.

Intensive cropping: Growing number of crops on the same piece of land during the given period of time.

Land Equivalent Ratio

Land Equivalent Ratio: Used to measure the land productivity.
It is often used as an indicator to determine the efficacy of intercropping (Brintha and Seran, 2009).

The LER is the ratio of land required by pure (sole) crop to produce the same yield as that of intercrop was determined according to the following formula: LER = Yield A in mixed stand/Yield A in pure stand + Yield B in mixed stand/Yield B in pure stand
Thus, LER is a *standardized index* that is defined as the *relative area required by sole crops* to produce *the same yield as intercrops* (Mead and Willey, 1980).

Cropping index and Cost Benefit Ratio

Cropping Index: Growing more than one crop in a year increases the benefit. If three crops in two years are grown instead of two crops in two years in the field, the benefit is greater.

Cropping Index = No. of Crops/No. of years *100

Monetary benefit: The benefit of crop rotation is assessed in terms of money. This can be calculated as follows:

Net return (earning from the production of crop) = Gross return – Cost of cultivation

Cost benefit ratio = Gross return (output)/total cost of cultivation(Input)

INTENSIVE CROPPING Principles

- The turnaround period between one crop and another is minimized through modified land preparation. It is possible when the resources are available in plenty. Ex. Garden land cultivation. Cropping intensity is higher in intensive cropping system. Crop intensification technique includes intercropping, relay cropping, sequential cropping, ratoon cropping, etc. All such systems come under the general term multiple cropping.
- **Need for intensive cropping:** Cropping systems has to be evolved based on climate, soil and water availability for efficient use of available natural resources. The increase in population has put pressure on land to increase productivity per unit area, unit time and for unit resource used. This cropping system should provide enough food for the family, fodder for cattle and generate sufficient cash income for domestic and cultivation expenses.

a. Additive series: In this one crop is sown with 100% of its recommended population in pure stand which is known as the base crop. Another crop is known as intercrop, is introduced into the base crop by adjusting or changing crop geometry. The population of intercrop is less than its recommended population in pure stand.

b. Replacement series: In these both the crops are called component crops. By scarifying certain proportion of population of one component, another crop introduced.

Maharashtra:
1. Cotton – Jowar/ Bjra, Cotton – Jowar – Groundnut.
2. Sugarcane – Rice – Gram.
3. Cotton – Groundnut, Cotton – Jowar/ Bajara – Groundnut.
4. Sannhemp – Sugarcane.
5. Pre Cotton – R.Jowar/ Wheat/ Gram.
6. Rice – Gram.
7. Groundnut – Cotton – Jowar.

Marathwada:
1. Mung – Jowar – Cotton + Tur
2. Sunflower – Jowar.
3.Soybean – Jowar/ Safflower/ Gram.
4. Hy. Jowar – Gram / Sunflower / Safflower.
5. Bajara – Gram, Mung/Urd/ Soybean – R.Jowar, Safflower.

Irrigated:
1. Cotton – Groundnut, Sannhemp – Sugarcane – Groundnut.
2. Rice – Gram/ Sunflower.
3. Hy. Jowar – Wheat/ Jowar/ Gram.
4. Jowar – Sunflower – Groundnut.
5. Sunflower – Potato – Groundnut.
6. Groundnut – Wheat – Vegetables.
7. Sorghum – Wheat – Green gram – Cotton – Groundnut.
8. Bajara – cabbage – Groundnut – Cotton – Groundnut.

Mixed Cropping: It is the process of growing two or more crops together in the same piece of land simultaneously (at same time). Wheat is mixed with peas, gram or mustard; Cotton is grown mixed with sunflower. It is practiced by farmers to avoid total crop failure due to decreased rainfall. It si also a means of storing soil fertlility as waste materials from both crops support growth of both the crops and vice versa. Wheat+ Chickpea; Maize+ Bean, Barley+chickpea, soybean+ Pigeonpea,Groundnut+Sunflower. Factors affecting mixed cropping:

The objectives are:

1) To get handy installments of cash returns especially in irrigated crops,
2) To achieve better distribution of labour throughout the year,
3) To utilize available space & nutrients to maximum extent possible,
4) To safe guard against hazards of weather, diseases & pests,
5) To secure daily requirements like pulses, oilseeds, fibers, etc.
6) To get balanced cattle feed.
In order to obtain the maximum benefit from the subsidiary crop mixed with the main crop, it should have the following characteristics: It should
i) Not abstract the growth of the main crop,
ii) Mature earlier or later than of the main crop,
iii) Preferably be a legume,
iv) Have diff. growth habits & nutrient requirements,
v) Have diff. rooting depths & ramification and
vi) Not be very exacting in climatic requirements.

Mixed cropping:

1) Mixed crops: Mixing of seeds and raising two – three crops at the same time & in same field. E.g.: *Jowar/*wheat +mustard/ gram.
2) Companion Crops: Different crops are sown in different rows. E.g.: 6 to 8 rows of cotton + 2 to 3 lines of Tur, 4 – 6 rows of Jowar + 1 – 2 lines of Tur, Jowar + Mung/Urd, Jowar + Safflower.
i) Guard crops: Growing hardy or thorny crops (Mesta/Safflower) around the main crop (Jowar/Wheat)
ii) Augmenting crops: Growing sub-groups (augmenting) to maintain the yield of main crop. F. Jowar/Bajara + Cowpea.

	MIXED CROPPING	MULTIPLE CROPPING
1	Cultivation of two or more than two crops simultaneously on the same land without definite row pattern or fixed ratio.	Growing of two or more crops on same field in a year(same piece of land in a growing season); it is more like intensification of cropping i.e. more number of crops within a year and more number of crops on the same piece of land at any given period. It could be done in various types inter cropping, mixed cropping, sequential cropping and relay cropping.

2	Sowing of seed is generally by broadcasting method	Sowing of seed could be both sowing at certain distance in rows or broadcasting.
3	Commonly practiced in dryland areas	Commonly practiced in irrigated fertile land
4	Key objective of mixed cropping is to lessen the risk of total crop failures and to satisfy the farmers with food and fodder both.	Key objective is to maintain soil fertility.
5	Its scientific study was first done by La-Flitze (1928)	Also called poly culture (relay, double, companion planting)
		Tomator+marigold+onion (may be harvesting could be done at different times) . After green revolution, duration for growing rice is shortened from 150-180 days to 100 days leading to cultivation of multiple crops in the same field.

Sr. No	**Inter Cropping**	**Mixed Cropping**
1	The main object is to utilize the space left between two rows of main crop	To get at least one crop under favorable conditions
2	More emphasis is given to the main crop	All crops are cared equally
3	There is no competition between both crops	There is competition between all crops growing
4	Inter crops are of short duration & are harvested much earlier than main	The crops are almost of the same duration
5	Sowing time may be same or different	It is same for all crops
6	Crops are sown in different rows without affecting the population of main crop when sown as sole crop	Either sown in rows or mixed without considering the population of either

Fallow: is the practice of allowing crop land to lie idle during a growing season to build up the soil moisture & fertility content so that a better crop can be produced in the following year. A fallow year or season is one in which the field is not cultivated with any crop but left without a crop. The field may be left undisturbed in a ploughed condition or kept clean by frequent cultivations. It is usually worked periodically to control weeds and improve moisture infiltration.

Points to be considered for planning the crop rotation: Farmer should consider the following factors while planning the crop rotation

1. Net profit.
2. Growth habit & nutrient requirements of different crops.
3. Effect of one crop on the other hand that is succeeding.
4. Soil type & slope &
5. Infestation of weeds, diseases & pests.
These factors should be considered to set the good crop rotation based on these factors; one should also consider the following points:
1. A shallow rooted grain crop, a deep rooted cash crop and a restorative crop should be included in the rotation which will provide food, fodder & cash to the farmer & maintain soil productivity.
2. The selection of crops should be made, taking into consideration soil, climate & market demand.
3. In case of irrigated areas, the rotation should be fixed on the extent of availability of water supply so that 2 or more crops can be taken from the same field in one year.
4. In case of rain fed areas, if sufficient moisture is left over in the soil after the harvest of *Kharif* crops, some minor crops requiring less moisture like pulses may be grown.
5. Both wide row spaced crops & thickly planted crops should be included.
6. Crops of diverse botanical relationship should be alternated as an insect or disease will attack closely related species but will not injure unrelated species.
7. A logical sequence of crops should be set up making full use of all available information as to effect of each crop in rotation on the succeeding crops to ensure maximum yields & higher quality.
8. Ordinarily, the area devoted to each crop should be consistent acreage from year to year.
9. Enough elasticity may be kept in the rotation.
10. depending upon the soil type, i.e. more or less fertile, low lying, acidic or alkaline soils, stress should be gien to the crop rotation considering its importance.
11. Importance, location of farm and region base crops should be included in the crop rotation.
12. Legumes should be included in the crop rotation with non-legumes as it is multi advantageous crop such as fixes atmospheric nitrogen, covers the land so prevent erosion, smother weeds.

10 CROP DENSITY & OPTIMUM PLANT POPULATION

What are plant ideotype and its types?
In systematics, an ideotype is a specimen identified as belonging to a specific taxon by the author of that taxon, but collected from somewhere other than the type locality. The concept of ideotype in plant breeding was introduced by Donald in 1968 to describe the idealized appearance of a plant variety.
According to Donald, ideotype is a biological model which is expected to perform or behave in a particular manner within a defined environment: "a crop ideotype is a plant model, which is expected to yield a greater quantity or quality of grain, oil or other useful product when developed as a cultivar." Donald and Hamblin (1976) proposed the concepts of isolation, competition and crop ideotypes.
1 Market ideotype

2 Climatic ideotype
3 Edaphic ideotype
4 Stress ideotype
5 Disease/pest ideotypes are its other concepts. The term ideotype has the following synonyms: model plant type, ideal model plant type and ideal plan type.

Crop Density

Crop density is just the number of plants within a given sample unit area i.e. per meter square. Is the number of plants of a certain species in a particular area -- is determined by counting the number of individual plants of a species in uniformly sized sample plots within a site. The size of the sample plots depends on the size of the plants being measured. Researchers frequently use a quadrat frame to define sample plots. Plant density is used to help determine the percentage of germination in a field, the number of invasive weeds present to assess control measures and to track plant population changes over time

Optimum density

The optimum density or plant population for any given situation results in mature plants that are sufficiently crowded to efficiently use resources such as water, nutrients, and sunlight, yet not so crowded that some plants die or are unproductive. Maintaining the optimum plant population and competition in field crops right from germination to harvesting is one of the important tasks for efficient utilization of resources and to get highest economical yield.

Crop density and crop yield relationship

Yield–density models describe the functional relationship between the yield of a crop and density of planting. Such relationships are important for determining the optimum plant population level giving maximum yield per unit area.
Two broad forms of yield–density models have traditionally been studied, namely, those classified as either asymptotic or parabolic (Holliday, 1960). Let:
Y = crop yield (dry matter) per unit area
X = density (plant population in number of plants sown per unit area (this notion can also be stated in terms of spatial arrangement
W = Y/X = mean crop yield per plant

If with increasing density Y rises to a maximum and then becomes relatively constant at high densities, then the yield–density relationship is said to be *asymptotic* (Fig. 7.1a). And if Y attains a maximum and then declines with increasing density, then the yield–density relationship is termed *parabolic* (Fig. 7.1b). While some yield–density equations involve a relationship between crop yield per unit area (Y) and plant density (X), the vast majority of yield–density models propose a functional relationship between mean yield per plant (w) and density (Fig. 7.1c).

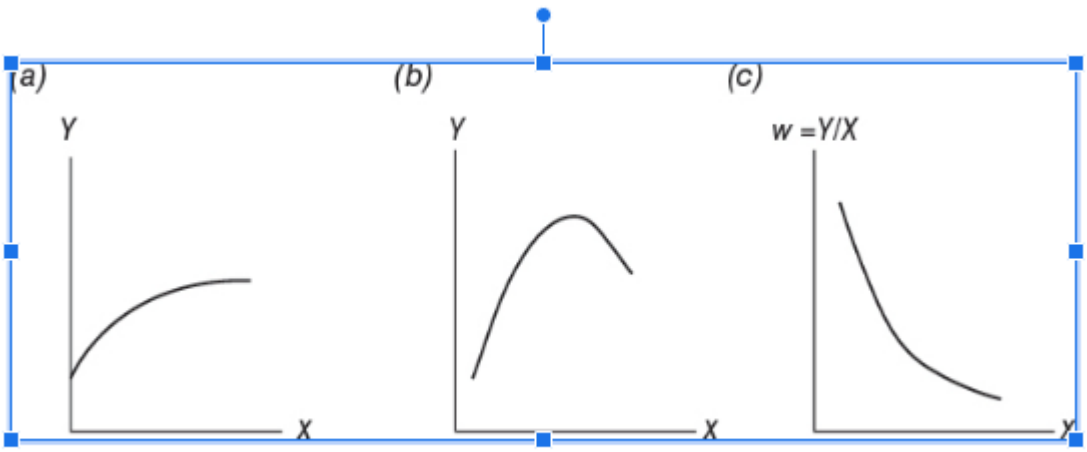


FIGURE 7.1 Yield–density functions: (**a**) asymptotic; (**b**) parabolic; and (**c**) decreasing mean yield.

Factors affecting optimum plant population

Many factors influence the optimum plant population for a crop: availability of water, nutrients and sunlight; length of growing season; potential plant size; and the plant's capacity to change its form in response to varying environmental conditions (morphological plasticity).

Plant population could be affected by seeding date, seeding depth, seeding at high rate of speed, poor seed quality, seed-row fertilizer a bit hot for the seed, excessive or poorly distributed crop residue, diseases or insect damage, poor soil tilth and/crusting, high or low pH and carry-over of herbicide residues.

The factors affecting plant density

Optimum plant density depends on size of the plant, elasticity, foraging area, nature of the plant, capacity to reach optimum leaf area at an early date and seed rate used. The factors affecting plant density are grouped into two as

A. Genetic Factors (plant or internal factors)

(i) Size of plant – The volume occupied by the plant at the time of flowering decides the spacing of the crop. Plants of red gram, cotton, sugarcane etc., occupy larger volume of space in the field compared to rice, wheat, ragi, etc. Even the varieties of the same crop differ in size of plant.

(ii) Elasticity of the plant – Variation in size or plant between the minimum size of the plant that can produce some economic yield to the maximum size of the plant that can reach under unlimited space and resources is the elasticity of the plant. The optimum plant density range is high in indeterminate plants. For example, in indeterminate red gram varieties the optimum plant density ranges from 55 to 133 thousand plants/ha. The elasticity of plants is due to branching or tillering. For determinate plants like maize, sorghum etc., the elasticity is less and hence the optimum plant density range is small. The removal of auxiliary buds is done to get uniform and early maturity in castor.

(iii) Foraging area or soil cover – The crop should cover the soil as early as possible so as to intercept maximum sunlight. More interception of solar radiation leads to more dry matter production. Closely spaced plants intercept more radiation than widely spaced plants. Area of root spread also decides the density.

(iv) Dry matter partitioning – Dry matter production is related to the amount of solar radiation intercepted by the canopy, which depends on the plant density. As the plant density increases, the canopy expands more rapidly, more radiation is intercepted and more dry matter is produced.

B) Environment factors.

(i) Time of sowing – The crop is subjected to different weather conditions when sown at different periods. Among the weather factors, the most important factors that influence optimum plant density are day length and temperature. Photosensitive varieties respond to day length resulting in change in size of the plant. As low temperature retards the growth, higher density is established for quicker ground cover.

(ii) Rainfall/irrigation – Plant density has to be less under rainfed than irrigated conditions. Under higher plant densities, more water is lost through transpiration. Under adequate irrigation or under evenly distributed rainfall conditions, higher plant density is recommended.

(iii) Fertilizer application – Higher plant density is necessary to fully utilize higher level of nutrients in the soil to realize higher yield. Nutrient uptake increases with increase in plant density. Higher density under low fertility conditions leads to development of nutrient deficiency symptoms. For example, rice does not respond to plant density without nitrogen application.

(iv) Seed rate – Quantity of seed sown/unit area, viability and establishment rate decides the plant density.

Crop geometry

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

- Wider spaced crops have advantage under this geometry
- Plants which requires no restriction in all directions are given square geometry
- Usually perennial vegetation like trees/shrubs are under this arrangements

(i) ***Square planting***

Square arrangements of plants will be more efficient in the utilization of light, water and nutrients available to the individual plants than in a rectangular arrangement.

(ii) ***Rectangular planting***

Sowing the crop with seed drill, wider inter-row and closer intra-row and closer intra-row spacing leads to rectangularity. Rectangular arrangement facilitates easy inter cultivation. Rectangular planting mainly suits annual crops, crops with closer spacing etc., the wider section (row) is given for irrigation, intercultural operation etc.

- It is an arrangement to restrict the endless growth habit in order to switch over from vegetation to the productive phase.
- This method accommodate high density planting

• It can facilitate intercropping also.

(iii) ***Triangular planting*** –
It is a method to accommodate plant density under perennial/tree crops.

(iv) ***Miscellaneous planting***
In rice and ragi transplanting is done either in rows or at random. Skipping of every alternate row is known as skip row planting. When one row is skipped the density is adjusted by decreasing inter-row spacing. When the inter row spacing is reduced between two rows and spacing between two such pair are increased then it is known as pairedrow planting. It is generally done to introduce an inter crop.

11 Rain fed farming and water harvesting

Dry land farming

Dry land farming and dry farming encompass specific agricultural techniques for the non-irrigated cultivation of crops. Dry land farming is associated with dry lands, areas characterized by a cool wet season (which charges the soil with virtually all the moisture that the crops will receive prior to harvest) followed by a warm dry season. They are also associated with arid conditions, areas prone to drought and those having scarce water resources.

Rain fed Farming

Rain fed agriculture is a type of farming that relies on rainfall for water. It provides much of the food consumed by poor communities in developing countries. Rain fed farming constitutes 80% of the world's cropland and produces more than 60% of the world's cereal grains, generating livelihoods in rural areas while producing food for cities. In temperate regions with relatively reliable rainfall and good soils, rain fed agriculture generates high yields.

Dryland vs Rainfed farming

Constituent	Dryland farming	Rainfed farming
Rainfall (mm)	Less than 800	More than 800
Moisture availability	Shortage	Enough
Growing season (days)	Less than 200	More than 200
Growing regions	Arid and semiarid	Humid and sub humid
Cropping system	Single or intercropping	Intercropping or double cropping
Constraints	Wind and water erosion	Water erosion

Water harvesting

The term 'water harvesting' generally refers to the collection of rainstorm-generated runoff from a particular area (a catchment) in order to provide water for human, animal, or crop use.

Methods of Rooftop Rainwater Harvesting

- Storage of Direct Use. In this method, rainwater collected from the roof of the building is diverted to a storage tank.
- Recharging Groundwater Aquifers.
- Recharging of Bore Wells.
- Recharge Pits.
- Soakway or Recharge Shafts.
- Recharging of Dug Wells.
- Recharge Trenches.
- Percolation Tank.

Why do we Harvest Rainwater?

The rainwater harvesting system is one of the best methods practised and followed to support the conservation of water. Today, scarcity of good quality water has become a significant cause of concern. However, rainwater, which is pure and of good quality, can be used for irrigation, washing, cleaning, bathing, cooking and also for other livestock requirements.

Advantages of Rainwater Harvesting

The benefits of the rainwater harvesting system are listed below.

- Less cost.
- Helps in reducing the water bill.
- Decreases the demand for water.
- Reduces the need for imported water.
- Promotes both water and energy conservation.
- Improves the quality and quantity of groundwater.
- Does not require a filtration system for landscape irrigation.
- This technology is relatively simple, easy to install and operate.
- It reduces soil erosion, storm water runoff, flooding, and pollution of surface water with fertilizers, pesticides, metals and other sediments.
- It is an excellent source of water for landscape irrigation with no chemicals, dissolved salts and free from all minerals.

Disadvantages of Rainwater Harvesting

- Regular maintenance is required.
- Requires some technical skills for installation.
- Limited and no rainfall can limit the supply of rainwater.
- If not installed correctly, it may attract mosquitoes and other waterborne diseases.
- One of the significant drawbacks of the rainwater harvesting system is storage limits.

Importance of Rain fed farming in Nepal 1

Examples of methods for reducing excess soil moisture loss include following:

- **Spreading manure or compost over the soil** – this minimizes evapotranspiration and also provides valuable nutrients to the soil through processes of decomposition
- **Mulching** – mulch is a layer of organic (or inorganic) material that is placed on the root zone of the plants. Examples of mulch materials include straw, wood chips, peat. Inorganic mulch in form of plastic sheeting is also used. Mulching is most suited for low to medium rainfall areas, and less suited for areas with very wet conditions.
- **Conservation tillage** – reducing or, in extreme cases, completely eliminating the tillage to maintain healthy soil organic levels which increases the soils capacity to absorb and retain water. Conservation tillage is a specific type of such approach where crop residue is left on the soil to reduce evapotranspiration, and protect soil surface from wind, sun and heavy rain impacts.
- **Crop rotation** – growing different types of crops every season helps improve soil structure and thus water holding capacity. Examples include rotating deep-rooted and shallow rooted crops that make use of previously unused soil moisture, as plants draw water from different depth levels within the soil. Crop rotation may also improve soil fertility and help control pests and diseases.
- **Green manuring** – growing of plant materials with the sole purpose of adding to the soil for improved organic matter and nutrients. The improved soil quality then also improves water retention capacity.
- **Deep tillage –** suited for some areas and soils, deep tillage can help increase porosity and permeability of the soil to increase its water absorption capacity.
- **Mixed cropping and inter planting** - cultivating a combination of crops with different planting times and different length of growth periods.
- **Contour ploughing –** by ploughing the soil along the contour instead of up- and downward slopes, the velocity of runoff is reduced, creating even barriers, and more water is retained in the soils and distributed more equally across the cropland.
- **Strip cropping -** growing erosion permitting crops and erosion resisting crops in alternate strips. Other soil moisture conservation techniques may include rainwater harvesting to minimize runoff and collect water for use on site. For more technologies on this see technology sheet Rainwater harvesting for infiltration.