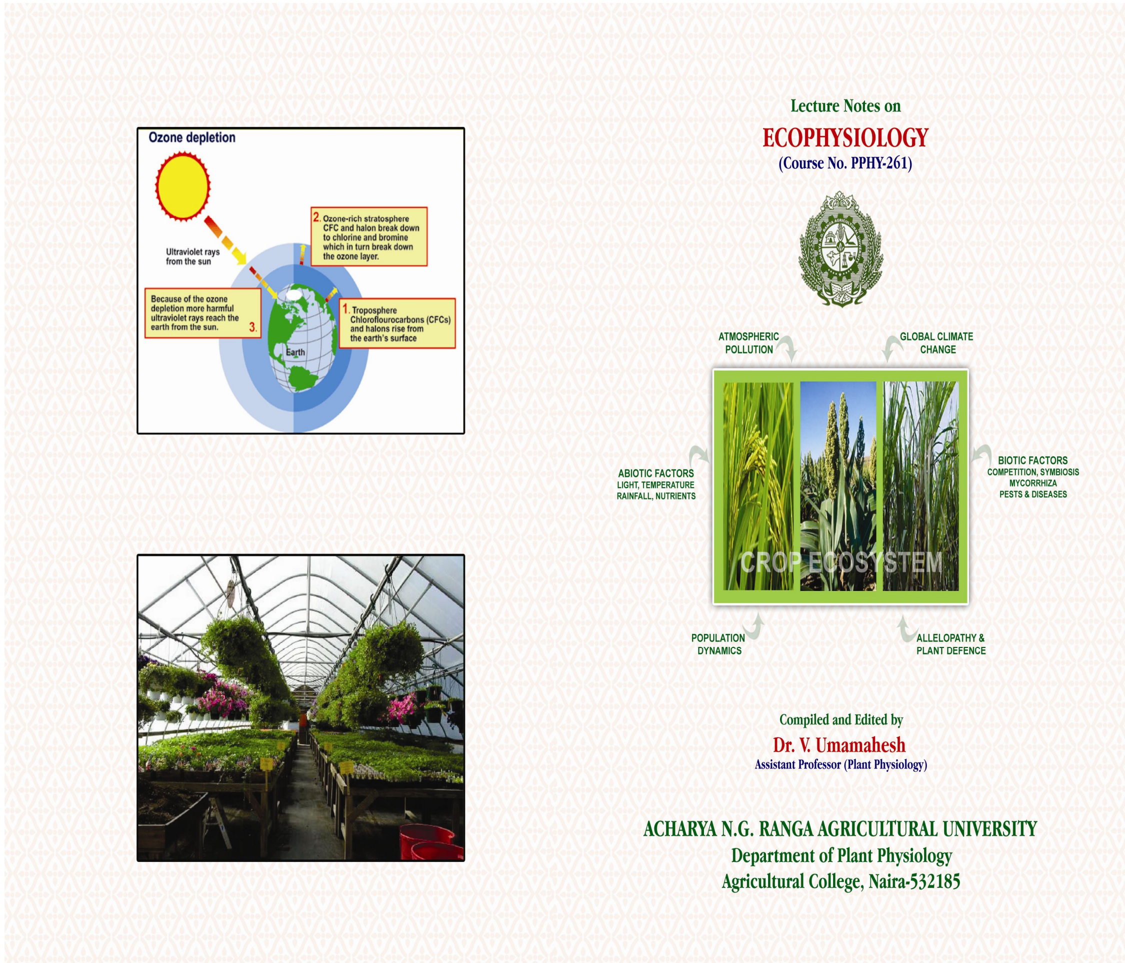


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# ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY

## Department of Plant Physiology

## Detailed Lecture Outlines

1. COURSE NO : PPHY 261
2. COURSE TITLE : ECOPHYSIOLOGY
3. CREDIT HOURS : 2(1+ 1)
4. GENERAL OBJECTIVE : To impart knowledge to the students on the environmental factors and their effect on plants.
5. SPECIFIC OBJECTIVES :

**a)** Theory

By the end of the course, the students will be able to

I. Study the ecophysiological aspects of plants

II. know about pollution and its effect on plant growth

III. understand controlled environment and its use in agriculture

**b)** Practical

By the end of the practical exercises, the students will be able to

I. Understand the response of plants in relation to various environmental factors affecting plant growth and development

**A) THEORY LECTURE OUTLINES**

1. Ecophysiology - Introduction – Definition – Importance in Agriculture and Horticulture – Ecosystem- definition of ecosystem, ecotypes & ecads – Biosphere and Ecosystem: subdivisions of biosphere – pathways of energy in the biosphere – concept of ecosystem – components of ecosystem- Basic structure of ecosystem.
2. Different types of ecosystems – freshwater – marine – forest and crop ecosystem – Energy in Ecosystem – productivity – primary production – secondary production – types of food chains.
3. Global climate and crop distribution– Influence of climate on crop distribution (Rice, Wheat, Maize, Sorghum and Sugar cane)- Important climatic regions of the world- Agro-climatic zones of India -crop distribution in India and Andhra Pradesh.
4. Environment – Definition – components - Biotic and Abiotic environments- Biotic environment: Biotic factors and Anthropic factors, Abiotic environmet: Climatic, edaphic. Physiographic and pyric factors- Climatic factors – Radiation – effect of radiation on plant functions - Classification of ultraviolet radiation- effects of UV-B radiation.

5. Abiotic environment- Climatic factors- precipitation – forms of precipitation Effect of water deficit and water logging on plant processes– temperature- Cardinal temperature- effects of temperature on plant processes – temperature injuries – high temperature and low temperature stress- classification of plants based on heat resistance and cold resistance – heat units.
6. Abiotic enviromemnt- Edaphic factors – Classification of plants based on adaptation to different soil types – halophytes and salt stress tolerance mechanisms.
7. Abiotic environment – physiographic factors, Altitude of the place – steepness of the slope, direction of mountain chain and exposure of the slope to light and wind- -effects of topographic factors on vegetation – wind effect on physiological processes.
8. Abiotic environment – pyric factors – sources and types of fires-Effects of fire on vegetation and environment – management of fires and rejuvenation of crops.
9. Biotic factors –herbivores (grazing effect), symbiosis (Mycorrhiza and Rhizobium associations), insectivorous plants, epiphytism and parasites Anthropic factors –industrialization-shifting cultivation –crop improvement.
10. Competition- Ecological Succession - dominance and subordination-types of competition- inter specific – intra specific and intra plant competition – Monoculture and Polyculture- Multistoried cropping system – mutual shading.
11. Allelopathy – Definition- concept – sources of allelopathic chemicals in crop and weed species –natural products identified as allelopathic chemicals– mode of action – scope for allelopathy.
12. Phyto-remediation-Definition – concept – Applications in Agriculture and Industry.
13. Pollution - Air pollution – Sources – Physiological effects on plants and its management. Water pollution – sources- physiological effects on plants and its management, soil pollution- sources- physiological effects on plants and its management.
14. Global warming – Green house effect – causes of global warming- methane, $Co_2$, Chloro Fluoro Carbon’s (CFC) and nitrous oxide (NO) gas, ozone – Impact of Global warming on climate and agricultural productivity – measures to reduce build up of Green House Gases.
15. Controlled environment – Purposes – types – designs of structures- commercial applications.
16. Carbon dioxide fertilization –definition-concept-importance- Sources – Methods of $CO_2$ fertilization – effects on crop yields and limitations; Ecophysiological Models – concept – models for different environmental management.

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1. Agarwal, K.C. 1999. *Environmental Biology.* Agro Botanica, Bikaner.
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**Lecture-1**

# ECOPHYSIOLOGY

## I.I INTRODUCTION

Eco physiology is a branch of plant physiology. It deals with the ecological control on growth, reproduction, survival, abundance, and geographical distribution of plants. It is well known that all these processes are affected by interactions between plants with their physical, chemical, and biotic environment.

German biologist Ernst Haeckel (1969) was first to propose the word Ecology (Greek; Oikos- house or place to live; Logos– study). Ecology is defined as the study of the relationship of organisms or groups of organisms with their environment. The questions addressed by eco physiologists are derived from "ecology" in its broadest sense. It also includes questions originating from agriculture, horticulture, forestry, and environmental sciences.

However, the eco physiological explanations often require understanding even at a lower level of integration of organisms (i.e. about physiology, biochemistry, biophysics and molecular biology).Ecophysiology also addresses some societal issues like pollution, climate change, conservation of nature etc. Thus, a modern eco physiologist requires a good understanding of both molecular aspects of plant metabolic processes and also functioning of an intact plant in its environment.

**I.2 Definition:** Eco physiology can be defined as the study of physiological response of organisms (plants) to their environment.

## I.3 IMPORTANCE OF ECOPHYSIOLOGY IN AGRICULTURE AND HORTICULTURE

Knowledge of ecophysiology is essential to understand the following broad areas of Agriculture and Horticulture

### 1.3.1 To understand the functional significance of specific plant traits and their evolutionary heritage.

$C_4$ and CAM plants are evolved from $C_3$ plants. In that process they have developed specific traits to adapt themselves to higher temperatures. This alteration in physiological mechanism of the plants with response to ecological changes can be explained better from an eco-physiological perspective.

### 1.3.2 To demarcate crops and their varieties to different agro systems

Ecological classification of plants based on their interactions with different environmental factors helps us to demarcate crops and their varieties for adoption and acclimatization to different agro systems. This is important for achieving qualitative and quantitative yields.

For example

a) Wheat is cultivated largely in North India because it requires low temperatures for germination and vegetative growth.
b) Sugarcane is a less yielder under Punjab climatic conditions as compared to that of Tamilnadu. (A warm summer season with less variation in mean monthly temperatures is the reason for higher cane yield in Tamilnadu.)

### 1.3.3 To develop stress resistant varieties

In general, animals are able to escape unfavorable and changing environmental factors such as heat, cold, drought, or floods, where as plants can not move away. They either have to endure the adverse conditions or to perish. Some Plants have an impressive array of genes which aid in adapting to wider range of changing conditions. This type of genetic variation helps us to understand stress resistant mechanisms and to breed resistant varieties

Some examples are given below:

- ✓ Salt resistant Rice cultivars SR-26B and Tellahamsa were developed by ANGRAU.
- ✓ Salt resistant Rice cultivars,CSR-1 and CSR-6 were developed at Central soil salinity Research Institute, Karnal,
- ✓ A drought resistant sorghum cultivar, M35-1 was developed in Maharashtra and is in adoption all over the country.
- ✓ A drought resistant Groundnut cultivar, Abhaya was developed by ANGRAU.

### 1.3.4 To manipulate environment for better crop growth

Better crop management always demands manipulation of crop growing environment. Weed free environment gives comparative edge for crop plants over weeds. Proper spacing of crop plants is maintained to reduce inter plant competition. Shelterbelts are positioned to protect crops from hot winds. These practices are certain ways of manipulating the crop growing environment. A clear understanding of the crop and its ecosystem helps in development of better management practices.

### 1.3.5 To understand location specific problems in a better way

In Northern Telangana zone, rice planted late in tail end areas of Sriram Sagar project suffers from low temperatures from the beginning of reproductive stage. Hence, Two thirds of panicle remains inside the boot leaf (panicle exertion).This problem has been very well tackled by developing lines which can exert panicle completely even under lower temperatures. Cold tolerant Rice varieties JGL 1798 and JGL 384 were thus developed by ANGRAU.

### 1.3.6 To cultivate crops under controlled environmental conditions

A complete knowledge on environmental requirement of plants, helps us to cultivate them under controlled environmental structures. Commercial cultivation of crops in Green houses and Poly houses has now become a flourishing enterprise.

Ex. Cultivation of Chrysanthemum, Tomato, Carnation etc,

Besides, simulation experiments are also being conducted under controlled environmental structures, to know the response of different crops to changing global climate.

## I.4 <u>SOME RELATED WORDS AND THEIR DEFINITIONS</u>:

### I.4.1 ECOSYSTEM

The term 'ecosystem' was first proposed in 1935 by the British ecologist A.G. **Tansley.**

Ecosystem is broadly defined as "the system resulting from the integration of all living (biotic) and non-loving (abiotic) factors of the environment. Thus, it refers to the sum total of all physical and biological factors operating in an area.

### I.4.2 ECADS OR ECOPHENES:

Ecads or the Ecophenes are the plants of the same species which differ in appearance such as size, stature and reproductive vigor etc. in differing environmental conditions. How ever, these variations are not genetically fixed and when transplanted to neutral conditions these variations are lost.

Ex: *Euphorbia hirta*.

- It shows prostrate growth when grown under disturbed conditions but erect under undisturbed conditions. If the prostrate type is transplanted to undisturbed locality it also grows erectly.

### I.4.3 ECOTYPES:

A species which is distributed in a wide range of geographical areas always develop some locally adapted populations called ecotypes. In simple, ecotypes are genetically distinct ecological races, where the variations are genetically fixed and irreversible. However, taxonomically they belong to the same species and can inter fertile among themselves.

EX: *Oryza sativa* (Asian Rice) - Branched panicle

*Oryza globerrima* **(**African Rice) - Un branched panicle.

As they belong to two different species, variations in this case can be expected. But with in the same species of *Oryza Sativa* there are three distinct ecological races or ecotypes or subspecies which show morphological, physiological and phenological variations (Indica, Japonica,Javanica). Existence of this variation forms the basis for breeding better varieties in paddy.

## I.5 BIOSPHERE AND ITS COMPONENTS( Sub divisions of biosphere)

The planet earth along with its living organisms and atmosphere (air, land and water) which sustain life is known as **biosphere**. Biosphere extends vertically into the atmosphere to about 10km, downwards into oceans to the depth of about 3500 ft and about 23000 ft deep from the earth's surface where living organisms are found.

Biosphere comprises of three major components.

(A) Atmosphere, - which includes air.

(B) Hydrosphere, - which includes rivers, lakes and oceans

(C) Lithosphere, - from which the soil is derived.

These three components interact in a controlled and organized manner. If any one of these components is destroyed the resulting damage is likely to be transmitted to the other two elements also.

Further, the **atmosphere** consists of three major divisions. (a) Troposphere (b) Stratosphere and (c) Ionosphere

**(a) Troposphere :** The part of the atmosphere with which plants and animals come into contact is called as troposphere. It consists of water vapor and clouds. This layer is only slightly transparent to radiation from the earth and is having much influence on all living organisms

**(b) Stratosphere :** The middle layer of atmosphere is known as stratosphere. It contains all the atmospheric ozone, which absorbs ultraviolet radiation. This prevents UV radiation reaching the troposphere arena and thus protects life on the Earth.

**(c) Ionosphere:** The uppermost layer is termed as ionosphere consisting of ionized particles. It reflects radio waves and thus making radio communication possible

**(B)Hydrosphere** is the envelope of water which covers a major part of earth's surface. It contains oceans and seas with marine waters, lakes and rivers with fresh water. Seas and oceans occupy more than two- thirds of the whole surface of the Earth. The oxygen content in water medium is far less as compared to atmosphere. Hence living organisms in this medium have to adapt to this prevailing conditions.

**(C) Lithosphere** is the earth's crust made up of different layers, like SIAL, made up with silicon and Aluminum, SIMA, which contains Silicon and magnesium and MANTLE, the densest part of the earth's crust.

The biosphere is not entirely hospitable to life and based on this fact biosphere is identified into two regions.

**Parabiosphere :** The region of the biosphere ,with severe environmental conditions which permits inhabitation for some organisms only.

Ex : Higher altitudes, cold Polar Regions and numerous localized regions such as volcanoes (burning mountains) geysers (a spring that throws forth intermittent jets of heated water) and highly polluted areas.

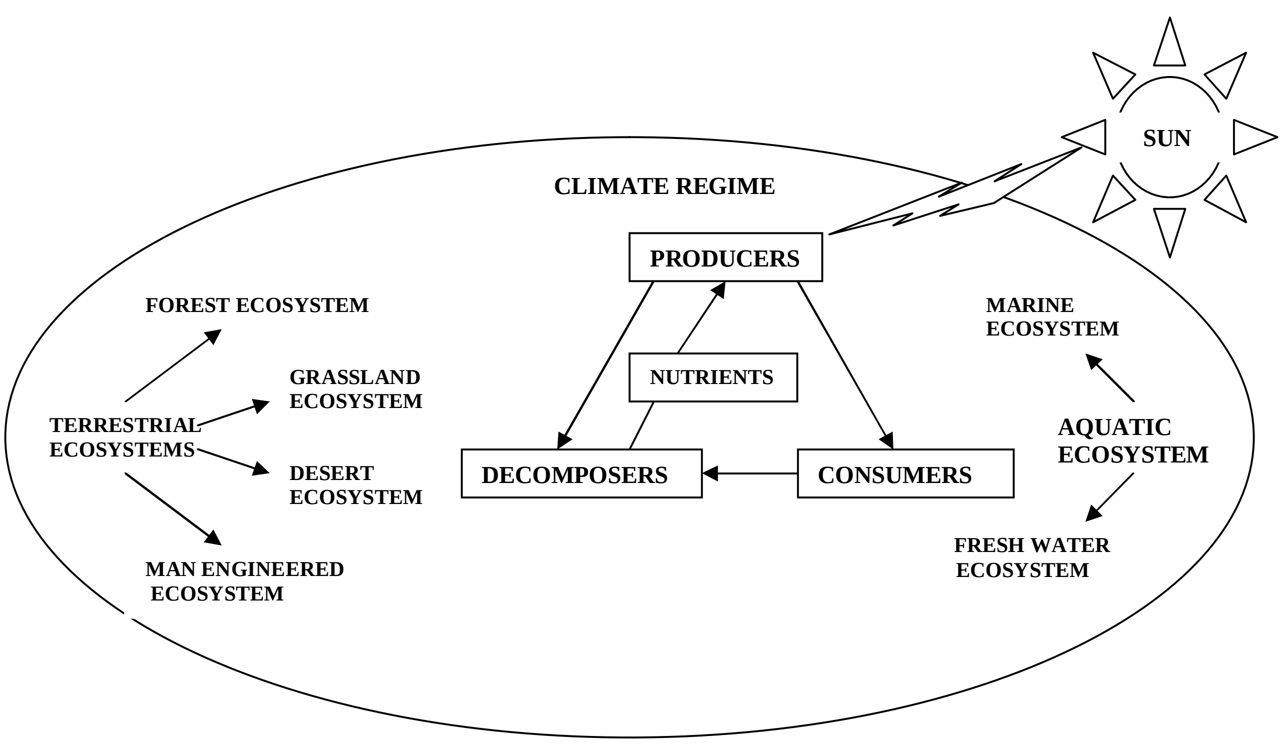
**Eubiosphere :** The region of the biosphere in which active metabolic processes of the organisms are possible. This region is hospitable for much of the organisms of the earth.

Modern ecologists fear that parabiosphere is increasing in size at the expense of the eubiosphere, owing to the destructive activities of man.

### I.6 <u>Pathways of Energy in the Biosphere</u>

The following diagram clearly illustrates how the energy is transferred from one component to the other.

The main source of energy in the entire universe is the Sun. The autotrophs or producers [Green plants and Photosynthetic bacteria] traps and converts this solar energy into chemical energy and stores it in the form of adenosine tri phosphate (ATP). Autotrophs are consumed by the consumer class and they may be primary, secondary or tertiary consumers. Producers and consumers after their death are subjected to decomposition by the decomposers, where the complex organic food substances storing energy are broken down in to simpler substances like sugars and nutrients. They are again taken up by the producers.




### I.7 CONCEPT OF ECOSYSTEM:

In the term ecosystem 'eco' implies the environment and 'system' implies an interacting and interdependent complex.

The whole 'biosphere' or 'giant ecosystem' may be viewed as comprising of many small units of ecosystems. Since it is difficult to study and understand the whole biosphere at a stroke, it is convenient to undertake a detailed study of small units of biosphere (ecosystems) and understand the manifestations of the larger unit (biosphere).

"**Thus ecosystem becomes the basic functional unit of ecology"**

An ecosystem may be as small as a drop of water from a pond (Micro ecosystems) or as large as an ocean (Mega ecosystem). The ecosystem can be of temporary (eg.Crop ecosystem) or permanent (eg. Forests and Oceans) in its nature. It may be of natural (e.g. forest, grassland, desert, lake, ocean ecosystem etc.) or artificial (Man engineered croplands of rice, sorghum, groundnut etc.) in its operation.

Which ever might be the Ecosystem, it basically regulates around the following **three basic themes**:

1. Interdependence: Ecosystem posses interacting and interdependent components. The ecosystems are either open or linked with each other.
2. Limitation: 'Limits' are natural in any ecosystem as no individual or species grows indefinitely. The total numbers always keep pace with the natural resources available.
3. Complexity: The interactions of various constituents of an ecosystem are highly complex and often beyond the comprehension of human brain.

## I.8 Components and structure of Ecosystem:

In general, any ecosystem has two basic components

1) Abiotic or non-living component

2) Biotic or living component

**1) Abiotic or non-living component:** It includes (a) Inorganic substances such as N, P, K etc. (b) Organic compounds such as carbohydrates, proteins, fats, etc. and (c) Climatic factors such as light, temperature, precipitation, wind etc.

**2) Biotic or living component:** The biotic components of the ecosystem can be divided into 3 groups:

**(a) Producers:** Green plants and Photosynthetic bacteria (eg. Chlorobium Chromatium,Rhodospirillum etc.) They convert light energy of sun into potential chemical energy (in the form of organic compounds). **Thus, producers are autotrophs in any ecosystem.**

The animals which are heterotrophs depend upon plant products for their food. But after digestion, the animals are capable of re synthesizing organic compounds like carbohydrates, proteins and fats. They could become food material for some other animals. Thus, the green plants are Primary producers and animals (heterotrophs) are known as **Secondary producers**.

**(b) Consumers:** These are heterotrophs, mainly animals including human-beings, which are incapable of synthesizing food material on their own and simply depend on green plants for food. Further consumers may be classified into 3 types:

1) **Primary consumers**: All the heterotrophs which live directly upon plant food are called as primary consumers. These are herbivores like, Grasshopper, Goat, Cow, Deer, Rabbit, Elephant etc.
2) **Secondary consumers*:*** They are heterotrophs and derive their food requirement from herbivores. These secondary consumers are **carnivores** E.g. Frog, Tiger, Lion etc.
3) **Tertiary consumers**: These are carnivores which feed on other carnivores (mostly Secondary consumers) e.g. snake.

**c) Decomposers:** They are also heterotrophic organisms which break down complex organic compounds of dead plants and animals and release inorganic substances which are made available to autotrophs. Since they consume some chemical substances for their own growth and reproduction they are also called as **microconsumers**. These decomposers play a very special and important role in the ecosystem

E.g. Bacteria, Actinomyces and Fungi.

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**Lecture-2**

## DIFFERENT TYPES OF ECOSYSTEMS

Ecosystems are classified as **natural ecosystems** (E.g. a pond, a lake, a river, a stream, a forest or a coral reef) and **Artificial or man engineered ecosystems** (E.g. crop ecosystems of maize, wheat, sugarcane, groundnut etc.). Another way of classification of ecosystems is as follows

**ECOSYSTEMS**

**Aquatic Ecosystems**
- Fresh water ecosystem
- Marine ecosystem

**Terrestrial ecosystems**
- Forest ecosystem
- Desert ecosystem
- Crop ecosystem
- Grass land ecosystem

**2.I Aquatic ecosystems:** The water ecosystems on the earth are mainly of two types (a) Fresh water and (b) Marine ecosystems

**2.I.I FRESH WATER ECOSYSTEM:** A pond is a good example of fresh water ecosystem. This is a self sufficient and self regulating system containing plants, animals and favorable, physico-chemical environment. Various components of a pond ecosystem are as follows.

**Abiotic environment**: It consists of heat, light, basic organic and inorganic compounds like water, $CO_2$ gas, calcium, nitrogen, phosphorus, amino acids, humic acid etc.

**Biotic environment:** Various biotic components are as follows:

**1) Producers:** These are autotrophic green plants and some photosynthetic bacteria. These producers fix radiant energy with the help of minerals derived from water and mud.

Producers in a fresh water ecosystem are of two types:

a) **Macrophytes**: these are mainly rooted large plants. They are submerged or Free floating or emergent hydrophytes.
E.g. Typha Nymphia, Chara, Hydrilla, Salvenia, Eichhornia, Lemna etc.

b) **Phytoplanktons:** These are minute, Suspended or floating lower plants.
E.g.Ulothrix, Spirogyra, Oedogonium, Volvox, diatoms, chlamydomonas etc.

**2) Consumers:** These are heterotrophs which may be herbivores or carnivores. Consumers are further divided into 3 groups:

**a) Primary consumers (herbivores):** These are herbivores feeding on living plants or plant remnants. These herbivores are further differentiated as (i) Benthos and (ii) Zooplanktons.

**(i) Benthos:** These are the animals associated with living plants. They are also called as detrivores, which feeds on plant remains lying upon the bottom of the pond. E.g. fish, insect larvae, beetles, mites, mollusks and crustaceans.

**(ii) Zooplanktons:** which are chiefly rotifers, such as Brachionus, Asplanchna or Lecane. They feed chiefly on phytoplanktons

**b) Secondary consumers (carnivores):** They feed on primary consumers (herbivores). They are mainly insects and fish which feed upon zooplanktons.

**c) Tertiary consumers (carnivores):** They are large fish such as game fish which feed upon small fish and thus become tertiary (**top**) consumers.

**NOTE:** In a pond, fish may occupy more than one tropic levels.

**3) <u>Decomposers</u>:** They bring about decomposition of plants and animals to simple form. They play an important role in returning of mineral elements back to the medium of pond.

E.g. bacteria, actinomyces and fungi.

### 2.I.2 MARINE OR OCEAN ECOSYSTEM

Oceans cover approximately 70% of earth's surface. Each ocean is a large and stable ecosystem.

The biotic components of ocean ecosystem are:

**1) <u>Producers:</u>** Producers in marine ecosystem are mainly phytoplanktons, diatoms, dinoflagellates etc.Large sea weeds like Sargassam and Rhododendran etc.

**2) <u>Consumers:</u>** They depend for their nutrition on primary producers.

a) **Primary consumers**: These are herbivores that directly feed on Producers

E.g. Crustaceans, mollusks and fish.

b) **Secondary consumers**: These are carnivores like big sized fish feeding on herbivores E.g. Herring, Shad, and Mackerel

c) **Tertiary consumers**: They are the Consumers of higher order (carnivorous) that feed on carnivores of Secondary consumer level.

E.g. Fishes like Cod, Haddock, and Halibut etc.

**3) <u>Decomposers:</u>** They are chiefly bacteria and some fungi .These microbes are active in decay of dead organic matter of Producers and macro consumers.

**2.2 TERRESTRIAL ECOSYSTEMS**: Under this heading Forest ecosystem and crop ecosystems are discussed here.

### 2.2.I FOREST ECOSYSTEM

The different components of forest ecosystem are:

**a) Abiotic component:** forest soil consists of minerals and accumulated dead organic debris. **Litter accumulation** and **complex stratification** are characteristic features of forest ecosystem.

**b) Biotic component:**

**1) Producers:** These are mainly trees that show much species diversity and greater degree of stratification in tropical forests. E.g. *Tectona grandis, Butea frondosa, Shorea robusta* etc. Besides trees, there are also shrubs and ground vegetation. In temperate forests the dominant trees are species of Quercus, acer, Betula, Thuja, etc,

**2) Consumers:** These are of three types:

a) **Primary consumers:** These are herbivores that include animals feeding on tree leaves such as ants, flies, beetles, leaf hoppers etc. and larger animals grazing on shoots and/ or fruits of Producers such as elephants, squirrels, flying foxes, etc.

b) **Secondary consumers*:*** These are carnivores feeding upon herbivores Ex. snakes, birds, lizards, fox, etc.

c) **Tertiary consumes***:* These are the top carnivores that eat carnivores of Secondary consumer level. Ex. lion, tiger etc

3) **<u>Decomposers</u>**: They include fungi (species of Aspergillus, Polyporus, Ganoderma, etc.), bacteria (species of Bacillus, Clostridium, Pseudomonas etc.) and actinomyces (E.g.species of Streptomyces etc.) Rate of decomposition in tropical and subtropical forests is more rapid than that of temperate forests.

### 22.2 CROP ECOSYSTEM

The crop ecosystems are artificial or man – engineered. In this, man makes much planned manipulations, in the physical and chemical environment of crop fields in order to obtain more yield. These manipulations include addition of fertilizers, use of pesticides, irrigation practices etc.

**Some of the characteristic features of crop ecosystems are as follows**.

- The crop ecosystem is chiefly a monospecific community with some weed associates.

- In natural ecosystem nature intends to maximize for gross production, where as in an artificial ecosystem, man wants to maximize the net production or the harvest index.
- Simplicity in structure and function of crop ecosystem, maintained in order to get maximum economic yield makes it fragile and susceptible to environmental stresses. Where as natural ecosystem is a complex community with many species and has the capacity to survive climatic hazards and pest damage.
- In a cropland ecosystem the crops are harvested and removed away from the site for human or cattle consumption. Hence, the crop fields always lose minerals and the soils are depleted of the nutrients (N, P,K etc). In order to maintain a high rate of production man has to add fertilizers in the crop fields. Functionally crop ecosystem/agro-ecosystem is characterized by high rate of energy and nutrient transfers.

The following are the chief components of crop ecosystem

**A) Abiotic environment**: It includes climatic conditions where the crop is grown and various minerals (particularly C, H, O, N, P, K) present in soil and atmosphere. Besides, Chemical fertilizers are also added to the soil.

**1. Biotic Structure:**

Most of the crops are seasonal, some are annuals and biannuals. The crops are maintained as pure population, though some weeds grow along with the crops. The biotic component of Agro-ecosystem is represented by producers, consumers and decomposers.

**a. Producers:**

Crops and weeds constitute the producers. The weed seeds are already present in the field or they are introduced along with the grain seeds at the time of sowing and also through irrigation water and animal agencies. For example in a maize crop the dominant species would be *Zea mays*. Besides, certain weeds like *Cynodon dactylon*, *Euphorbia hirta*, *Cyperus rotundus*, *Digitaria sp*. also appear. They also contribute to primary production of the field.

**b. Consumers:**

The homogenous stretch of producers in cropland ecosystem permits only a few animal representatives (consumers) to thrive and become part of the ecosystem. The crop provides shelter, site for laying eggs, protection from enemies and predators. Management practices like ploughing, irrigation, weeding etc, change the fauna of the soil and sometimes affect it drastically.

In a Maize crop ecosystem consumers are classified as follows.

a) **Primary consumers** (Herbivores): These are small animals mainly aphids, thrips, beetles etc. which feed and lay eggs on maize leaves. Larger animals include rabbits, rats and birds feeding on leaves and cobs of maize.

b) **Secondary consumers***:* These are carnivores like frogs and some birds that eat insects.

c) **Tertiary consumers***:* These are carnivores like snakes and hawks. They feed on secondary consumers like. frogs and small birds.

**c. Decomposers**

Ploughing , application of inorganic fertilizers, pesticides, herbicides, and the organic matter in the soil subsystem are some of the factors which influence the decomposer activity in the cropland ecosystem. Bacteria, actinomyces and fungi, are the chief decomposers responsible for decay, and humification. This process makes minerals available to producers.

## 2.3 ENERGY IN ECOSYSTEM

**Energy:**

Energy is defined as ‘ability to work’.

**Energy flow in an ecosystem:**

The energy that sustains all living systems is solar energy which is fixed in photosynthesis and utilized for the production of organic matter by the autotrophs (plants) as follows:

$$6CO_2+6H_2O+686\ Kcal \longrightarrow C_6H_{12}O_6+6O_2$$

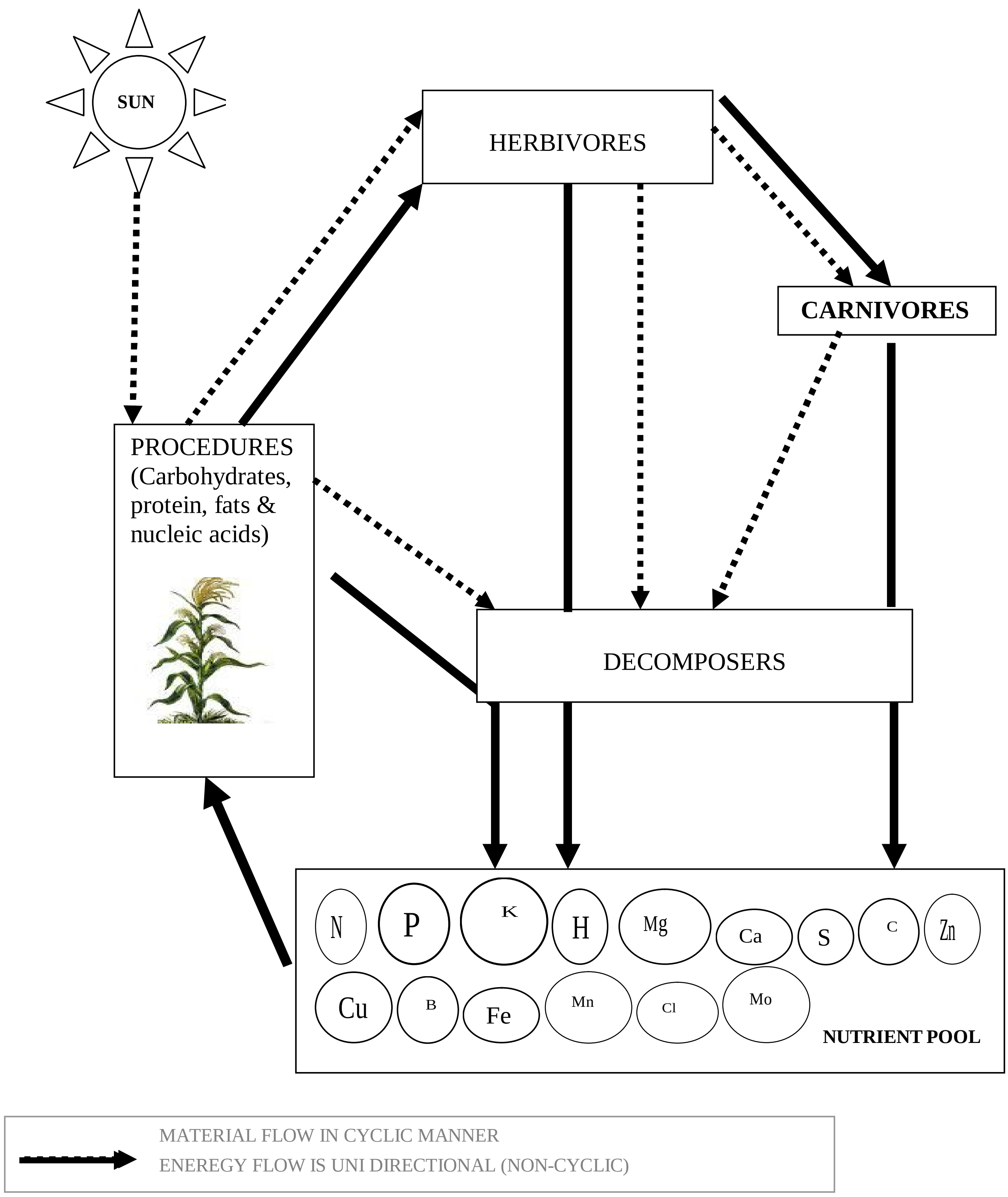
Plants are eaten by animals and the death of the plants and animals is ultimately followed by their decomposition. This process involves transfer of organic matter which can be equated in terms of energy. If we could measure the amount and the rate of transfer of organic matter from one organism to the other, we can build up a dynamic picture of that ecosystem. The flow of energy and materials is shown in figure.1

From figure.1 it is clear that the movement of energy in any ecosystem is unidirectional and the movement of materials is cyclic in nature. Energy conversion in to biomass depends upon the rate at which radiant energy is converted by Producers. Besides, by feeding on producers how much energy is assimilated by herbivores and carnivores also matters. This will decide the amount of energy finally available for decomposers? .For example, in a given period of time if ‘X’ amount of solar energy is converted by the producers this will become the maximum amount of energy available in that ecosystem. In that, if ‘Y’ amount of energy is lost in the process of its transfer from producers to consumers and then to decomposers, the amount of energy finally available for decomposers becomes ‘X-Y’. This X-Y fraction is the net energy that helps in decomposition of organic matter and release of nutrients. Therefore it should be noted that, more the energy fixed per unit time and unit area, more will be the flow of materials in that ecosystem in a cyclic manner.

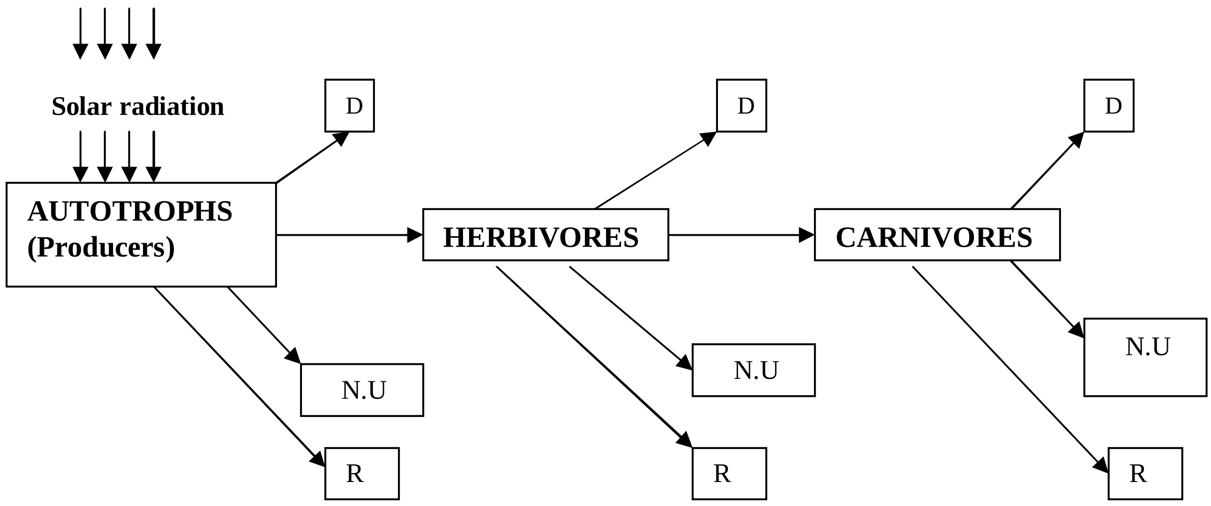
**2.4 PRODUCTIVITY:** The rate of production of organic matter per unit area in unit time is termed as productivity. There are two levels of production, primary and secondary. The amount of new organic matter resulting from photosynthesis (by producers) is termed as **primary production**, while **secondary production** occurs in herbivores, carnivores and decomposers, using materials synthesized in primary production. Further, at each level it can be distinguished into **gross production**, that is, the amount of organic matter produced; and **net production**, the amount of organic matter that remains after respiration.

$$\boxed{GP\text{-}R = NP}$$

Where GP = Gross productions, RS = amount used in respiration, NP = Net productions




However, in the process of energy flow, along with respiratory losses, there is loss of energy in decomposition and some portion of energy is even lost as rejecta (i.e. energy not utilized), only the remaining portion of energy is transmitted to the next tropic level. Thus, energy flow in an ecosystem depends not only on the size of producers and their rate of production but also depends upon Assimilation efficiency of producers, herbivores and carnivores.




**D:** DECOMPOSITION **N.U:** NOT UTILISED (REJECTA) **R:** RESPIRATORY LOSS

### 2.4.1 Primary production

The basic source of energy for the ecosystem is solar radiation. A surface exposed at right angles to the sun's rays outside the earth's atmosphere would receive energy at the rate of 1.94 cal / $cm^{-2}$ / min (SOLAR CONSTANT). This solar energy is effective only during day light hours and, because of absorption in passing through the atmosphere, scattering by smoke, dust particles and clouds, only 47% of the solar radiation reach the ground level. However, this varies with latitude, season and locality.

Green plants use this energy for photosynthesis. The leaf area of the plant is the best measure of photosynthetic size, and the most appropriate measure of leaf area is Leaf Area Index i.e. the leaf area per unit land area . In cropland ecosystems the LAI value is generally in the range of 2-6. In natural communities it may be as high as 6-13 (forest) and 3-15 (grasses). In annual crops LAI steadily rises with age, attains peak at flowering and than declines. LAI alone does not account for the total assimilatory surface of the plant, as stem and ears possessing chlorophyll add significantly to the photosynthetic efficiency of the plant.

Hence, in green plants, Chlorophyll content is correlated with the dry matter production. It is thus used as an index of productive potential of the plant population.

So long as the conditions are favorable for photosynthesis, the plants add new tissues, or store in excess of organic matter, and the net primary-productivity (NPP) has a positive value. But when conditions are unfavorable, the rate of NPP may fall to zero or even become negative / if respiratory losses exceed photosynthetic gains. The important factors that effect primary production are LAI and NAR. Besides high $Co_2$ concentration, leaf temperature, precipitation and nutrient status also plays an important role.

Considering the global primary production the amount of radiation reaching the earth's surface is approximately $3.5x10^{23}$ joules per year. Of this only 3-4% is fixed annually by plant tissues leading to global primary production of about $17x10^{13}$kg (dry weight) per year. The primary productivity differs in different ecosystems according to the prevailing conditions.

**Net primary productivity of various ecosystems**

| Ecosystem | Productivity ($gm^{-2}$ $yr^{-1}$) |
|---|---|
| 1. Desert scrub and tundra | 90-150 |
| 2. Temperate grass lands | 500 |
| 3. Tropical forests | 2000 |
| 4. Estuaries, swamps and marshes | 2000 |

**2.4.2 Secondary production:**

The organic matter formed as a result of primary production is channeled through the food chain to sustain the different organisms constituting the community within an ecosystem. Secondary producers consist of herbivores, carnivores and decomposers which can not synthesis their own food material, and depend on autotrophic producers (plants).

There are three basic types of food chains through which organic matter produced by plants can move.

**2.4.3 Types of food chains:**

**Grazing food chain:** Starts from a green plant base, goes to an herbivore and then to a carnivore.

**Detritus food chain:** Starts from dead organic matter, goes to microorganisms, then to detrivores and predators.

**Parasitic food chain:** Starts from a host, and passes through parasites and then to hyper parasites.

**2.4.4 Assimilation efficiency:**

Secondary production in Herbivores, Carnivores and decomposers can be understood from their assimilation efficiency. It is a ratio of total net primary production assimilated to that of total net primary production consumed. Assimilation efficiency is expressed as percentage

$$\text{Assimilation efficiency (\%)} = \frac{\text{Assimilation}}{\text{Consumption}} \times 100$$

**Lecture-3**

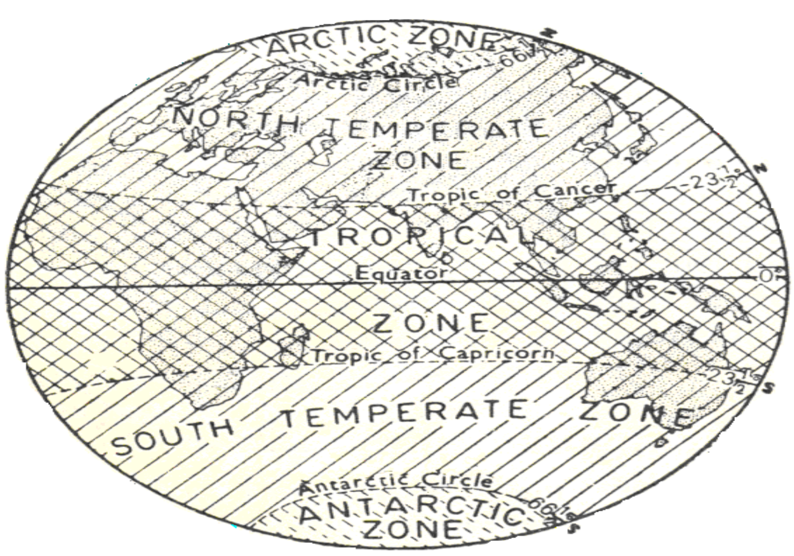
## GLOBAL CLIMATE AND CROP DISTRIBUTION

Climate is a long term mean of daily weather conditions as expressed by temperature, precipitation, pressure, winds and humidity at a specific place over a considerable period of time.

A climatic region is defined as an area on the earth surface where an approximately homogenous set of climatic condition is produced by the combined effect of climatic controls (mostly temperature & rainfall).

Temperature is regarded as basic factor of climate on the basis of which, the world has been divided into torrid/tropical, Frigid and temperate zones. Similarly rainfall pattern is also fundamental in establishing climatic regions on the globe as wet, humid, sub-humid, semi arid and arid zones. However, when it comes to the classification of global climate both temperature and rainfall were together considered by many scientists.

Among various classifications proposed on global climate Koppen's(1936), Thronthwaite's(1948) and Glen T. Trewartha's (1980) schemes have gained popularity. Out of which Trewartha's model is more relevant and simple. He had classified world climates in six great climatic groups where five are based on temperature criteria (Tropical humid, sub tropical, temperate, Boreal and polar) and the sixth group is based on precipitation (deserts and tropical grass lands which are dry in nature)




*A SIMPLE DIAGRAM EXPLAINING MAJOR CLIMATIC REGIONS OF THE WORLD*

### 3. 1 Influence of climate on Global crop distribution.

Successful cultivation of a crop in a particular area is largely decided by the climatic factors (eg.Temperature, Radiation / Sunshine, Rainfall) and edaphic factors of that particular locality.

Hot and humid nature of equatorial region shows severe pest and disease incidence. High evapo-transpiration in these areas is another limiting factor for cultivation of field crops. Therefore, only plantation crops like rubber, Oil palm, Cocoa etc., are grown here.

Crops that are adapted to higher temperatures (30-35$^{o}$c) are called as **tropical crops.** They are so susceptible to cold, that they even die at a temperature below 10$^{o}$c. Ex: Rice, Cotton, Sorghum etc.

Crops that are grown in subtropical and temperate regions, where lower temperatures prevail upon are called as **temperate crops**. In these areas, the **"growing season"** is the crucial factor for crop growth. Which otherwise decides how many months are congenial for crop cultivation. Here the growing season is the period between last frost in winter ( December, January and February) and the first frost in autumn(September, October and November))

**An example:** Mediterranean lands experience winter rains and summer drought. Here crop growth is almost restricted to autumn and spring when temp and moisture conditions are favorable. Only during these seasons cultivation of wheat is possible in Mediterranean and temperate grass lands.

(**Spring**: March, April, May;

**Summer**: June, July, August;

**Autumn**: September, October, November;

**Winter**: December, January, February)

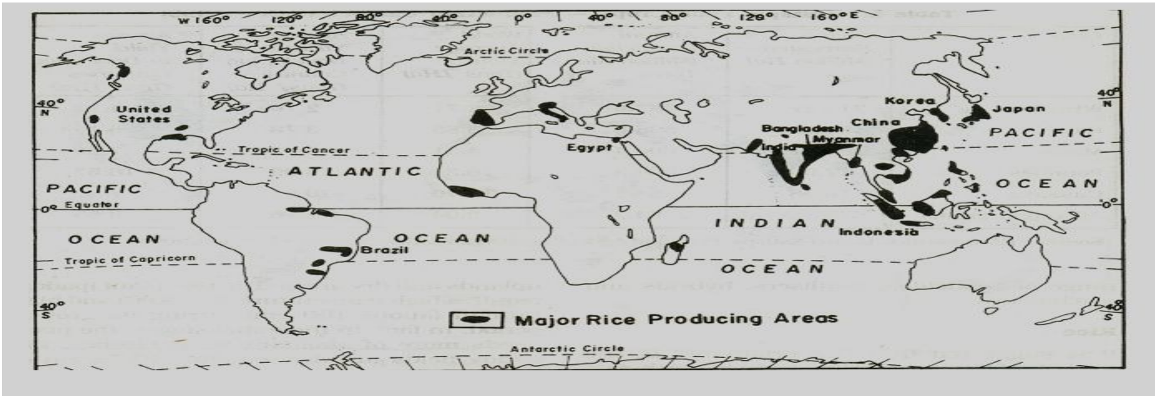
When we further move towards Polar Regions this growing season further constricts. Because, in Taiga regions there will be a snow cover for 5-7 months and in tundra's temperature is less than 0$^{o}$c for more than 9 months period, which allows us to grow very less number of crops here.

Thus, one should understand the fact, that, it is not possible to cultivate all the crops in all the climatic regions of the world.

## 3.2 PHYSIOLOGICAL BASIS FOR DISTRIBUTION OF SOME MAJOR CROPS IN VARIOUS CLIMATIC REGIONS OF THE WORLD

### 3.2.1 RICE:

Rice is a warmth loving crop requiring high temperature (27-30$^{o}$c), ample water supply (100cm rainfall) and high solar radiation at the last 35-40 days of its ripening period. Climatic requirements of rice crop are best available in tropical monsoon climate of Asian region. Where temperatures are high (around 32$^{o}$c) and never fall below 19-21$^{o}$c. Thus the top five producers of rice viz., **China, India, Indonasia, Bangladesh, Thailad** are located in this area. (FAO statistics 2008-09)

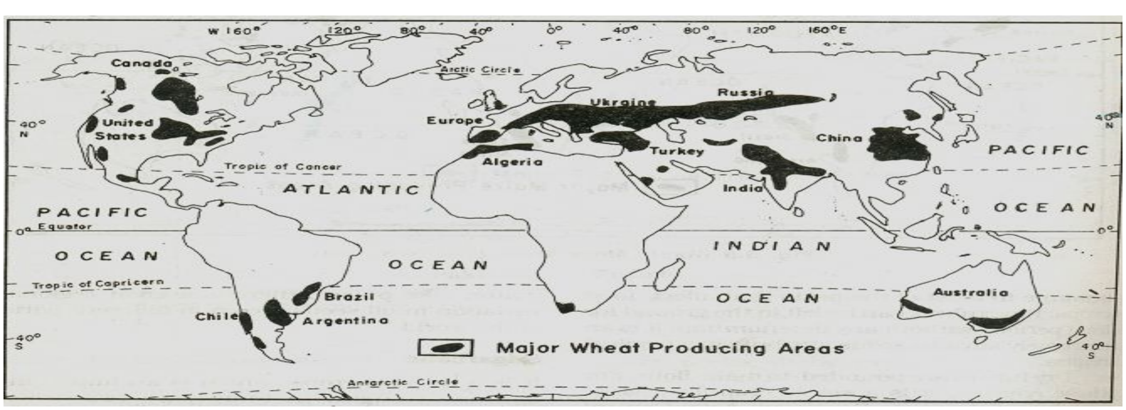



**3.2.2 Wheat:**

Wheat requires a cool weather during vegetative phase and warmth weather during its maturity. It needs an average temperature of 16$^{o}$c and a clear sky at the time of ripening. Temperature above 25-30$^{o}$c shows adverse effect on wheat growth. Thus, it is mainly grown in temperate regions like temperate grass lands and Mediterranean regions. To some extent it is also cultivated in subtropical regions also.

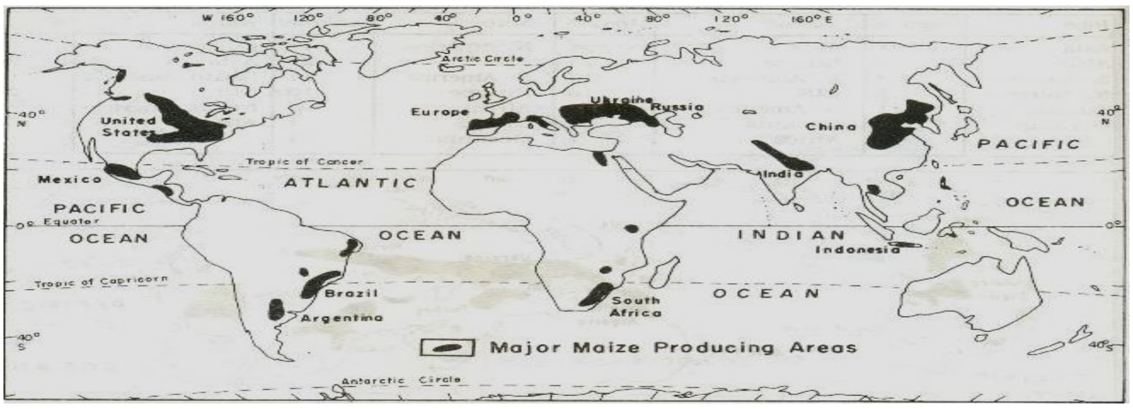
Major wheat producing countries are **EU 27, China, India, Russia, and U.S.**

**Note**: Wheat is a very hardy crop which shows great adoptability to various climatic regions. It needs an annual rainfall of 40-75cm only. Although yields and productivity levels are highest in temperate mid latitudes, the major wheat belts are in the drier semi arid climates. In dry tropical areas wheat is mainly cultivated because of it's lesser water requirement (Rainfall of 40-75cm). Half of the world has the possibility to get this much of rainfall. Thus, wheat is most extensively grown crop of the world.




**3.2.3 Maize:**

It grows best where the summers are warm and humid. About half of the world's maize is grown in U.S. (In U.S from central Ohio State to central Nebraska region corn is cultivated in a stretch of 1400 Kms which is popularly called as **Corn Belt**). Maize requires 34$^{o}$c temperature for its optimum growth and 21-30$^{o}$c for better tasseling.  The most essential climatic factor for maize is a 140 days frost free period.  Thus it is mainly grown in temperate regions. Major maize producers are The **U.S., China, EU-27, Brazil and Mexico**.




**3.2.4 Sorghum**:

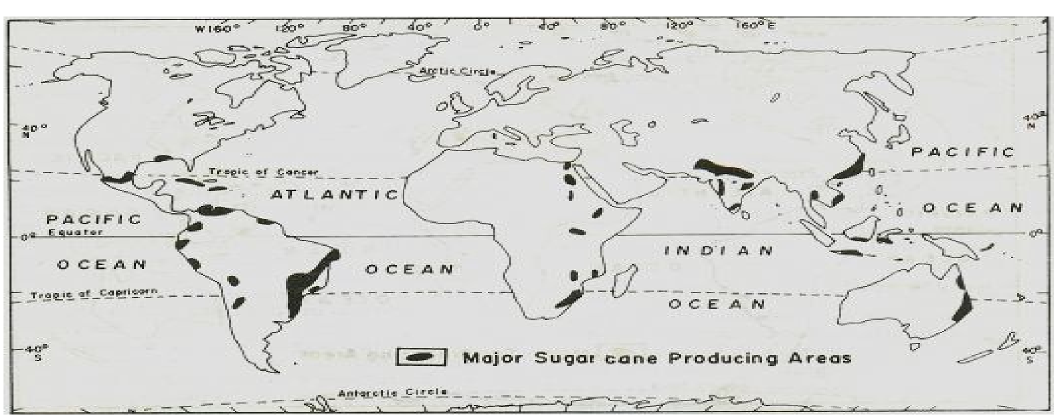
It is a major cereal crop of dry land agriculture in semi arid tropics. Maize in temperate regions is what sorghum in tropics.  It requires warm weather for development and it cannot grow well or set seed at temperatures below 18-21$^{o}$c.  It is thus grown in tropical and subtropical areas with low seasonal rainfall.

Major producers of Sorghum are **Nigeria, U.S. India, Mexico and Sudan.**

**3.2.5 Sugarcane:**

This is a tropical crop thrives best in hot and humid sunny areas. Temperatures ranging between 20$^{o}$c – 27$^{o}$c and a rainfall of 75-120cm are ideal for its growth.  Ideal climate for a one year crop would include at least 4-5 months with a mean daily temperature of 30-35$^{o}$c and 1.5-2.0 months of cooler temperatures prior to harvest which enhances sucrose accumulation.

Hence, it is largely grown in tropical monsoon and tropical grass land areas. Brazil (1/3 of world Sugarcane producing area), India, China, Thailand and Mexico are the lead producers of Sugarcane.



**3.3 Important Climatic regions – their latitudinal distribution, climatic characteristics and major crops cultivated**

| S. No | CLIMATIC REGION | LATITUDES | MAJOR CROPS CULTIVATED |
|---|---|---|---|
| 1 | EQUATORIAL REGIONS | $0^o – 10^o$ N&S | Mostly plantation crops like Rubber (Indonesia), Oil palm(Malaysia),Sugarcane(Brazil), Cocoa(Ghana) etc., are grown here |
| 2 | TROPICAL GRASS LANDS/ SAVANNAHS | $5^o – 15^o$ N & S | Millets, Groundnut, Maize, Cotton and Sugarcane are some of the field crops grown here. **Cuba** – popularly called as SUGAR BOWL OF THE WORLD is located in this region. Pineapples are grown in Hawaii Islands |
| 3 | TROPICAL MONSOON REGIONS | $10^o –30^o$ N & S | - Rice, Wheat, Maize, Sorghum, Sugarcane, Cotton, Jute and Tea are some of the important crops grown in this region.<br>-This is the major paddy producing zone of the world<br>-Largest sugarcane producing area is situated in this zone<br>--India & Bangladesh are the lead jute producers, where as India & Srilanka are the leading Tea producers of the world. |
| 4 | TROPICAL DESERT REGIONS | $15^o –30^o$ N & S | Dates are cultivated around oasis areas. Where irrigation is possible wheat, cotton, (Nile, delta) are grown. |
| 5 | MEDITERRANIAN REGIONS | 30-45 $^o$ N<br>30-40 $^o$ S | **Olive, Orange& Grape** cultivation is the main feature of this region, besides nuts (Walnuts, almonds) & Cereals like Wheat (in Australia) & Barley are also cultivated. |
| 6 | TEMPERATE GRASS LANDS REGION | 35-55 $^o$ N & S | This region is well known as **Wheat granary of the world**. Rice (in China), Maize (in U.S), Cotton, Tobacco & Soya are the other crops grown. |
| 7 | TAIGA REGION OR BOREAL CLIMATE | 50-70 $^o$ only in Northern hemisphere. At Southern hemisphere there is Antarctic ocean. | Potato, Turnip, Radish, are some of the crops grown during summer.<br><br>Cereals- Only rye and oats have some Significance in this zone. |
| 8 | TUNDRA REGIONS | 65-90 $^o$ N only | Lichens, sedges, mosses, butter cups, poppies are some of the plants grown. Crops cannot be cultivated here. |

**NOTE** - While understanding climatic regions of the world we should not expect fixed latitudinal zonation like 0-10 $^o$, 10-20 $^o$, 20-30 $^o$ etc., because of the local physiographic factors role in deciding the climate of a locality. Many a times a slight overlapping of latitudes for eg. 0-10 $^o$, 5-15 $^o$ etc., is quite common . Remember that, with in the same latitudinal width there may exist, more than one type of climatic conditions.

### 3.4 AGROCLIMATIC ZONES OF INDIA

An agro climatic region is a land unit in terms of major climate and growing period which is climatically suitable for a certain range of crops and cultivars (FAO,1983)

Planning commission of India (1984) has divided the country in to 15 Agro climatic regions on the basis of factors like soil type, rainfall pattern, temperature etc.,They are summarized in the following table

.

| AGRO CLIMATIC REGION | SPREAD |
|---|---|
| Western Himalayan Region | J&K, Himachal Pradesh, Uttar Pradesh and Uttaranchal |
| Eastern Himalayan Region | Assam, Sikkim, West Bengal and all North eastern states ( Meghalaya, Manipur, Mizoram, Tripura, Arunachal Pradesh, Nagaland) |
| Lower Gangetic Plains | West Bengal |
| Middle Gangetic Plains | Uttara Pradesh & Bihar |
| Upper Gangetic Plains | Uttara Pradesh |
| Trans Gangetic Plains | Punjab, Haryana, Delhi and Rajasthan |
| Eastern Plateau and Hill region | Maharashtra, UP, Orissa & West Bengal |
| Central Plateau and Hill region | Madhya Pradesh, Rajasthan & UP |
| Western Plateau and Hill region | Maharashtra, MP and Rajasthan |
| Southern Plateau and Hill region | Andhra Pradesh, Karnataka and Tamilnadu |
| East Coast plains and Ghat regions | Orissa, Andhra Pradesh, Tamilnadu and Pondicherry |
| West Coast plains and Ghat regions | Tamilnadu, Kerala, Goa, Karnataka and Maharashtra |
| Gujarat plains and hill regions | Gujarat |
| Western dry region | Rajasthan |
| The Islands regions | Andaman and Nicobar, Lakshadweep |

## 3.5 CROP DISTRIBUTION IN INDIA

Thornthwaite (1948) has identified 6 climatic zones in India according to the Moisture adequacy Index (annual rainfall). This classification is very useful to understand Crop distribution in India.

| S.No | Climatic Zone | Major crops | States come under zone | Remarks |
|---|---|---|---|---|
| 1 | Arid zone | Jowar and Bajra | Rajasthan, Gujarat | Rainfall is very low (<250mm).Distribution of rains is uncertain. Mostly It is a desert climate. |
| 2 | Semi arid zone | Jowar, Bajra, Maize, Groundnut, Castor | Parts of Rajasthan, Gujarat, Punjab and Mid Maharashtra | Rainfall is between 250-500mm.Dry farming regions of the country. drought is a recurrent phenomenon. Variation in rainfall is >25% |
| 3 &4 | Sub humid zone (Includes Dry sub-humid & Moist sub-humid zones) | Cotton, Jowar, Bajra, Wheat, Maize, Sugarcane, Mustard. | M.P,U.P, Karnataka, Orissa, Chattisgarh, Jharkhand West A.P, west Tamilnadu | 500-1000mm of rainfall. It forms an important area for crop production. Here rainfall variation is less than 20 per cent. So yields are better. |
| 5 | Humid zone | Rice, Pulses, Sugarcane | East U.P, Uttarakhand, Karnataka, Orissa,Eastern Tamilnadu,East AP Maharahtra | 1000-1500 mm rainfall. The condition for crop production is more stable. The principal crop of this region is Rice |
| 6 | Per humid zone | Rice, Jute | Assam, North west Bengal and North Eastern states. | Rainfall is >1500mm. |

## 3.6 CROP DISTRIBUTION IN ANDHRA PRADESH

| S.No | Agro climatic zone | Major crops cultivated |
|---|---|---|
| 1 | North Coastal Zone | Paddy, Sugarcane, Mesta, Sesame, Bajra |
| 2 | Godavari zone | Paddy, Pulses (Black gram, Green gram etc.,) |
| 3 | Krishna zone | Paddy, Cotton, Pulses, Chillies, Sugarcane |
| 4 | Southern zone | Paddy, Groundnut, Jowar, Sugarcane, Redgarm, Sunflower |
| 5 | Northern Telangana zone | Paddy, Maize, Groundnut, Sesame, Sugarcane, Jowar, Soya |
| 6 | Central Telangana zone | Jowar,Paddy,Pulses, Coarse cereals |
| 7 | Southern Telangana zone | Jowar, Maize, Bajra, Paddy, Castor, Sunflower, Groundnut |
| 8 | Scarce rainfall zone | Groundnut, Paddy,Cotton,Jowar,Sunflower, Bengal gram |
| 9 | High altitude zone | Paddy, Bajra, Maize, Ginger, Pineapple |

**Lecture-4**

## ENVIRONMENTAL VARIABLES

Maelzer (1965) defined the term environment as "**The sum total of everything that directly influences the organism's chances to survive and reproduce".** For an organism, the environment consists of all the surrounding physical and biological factors with which it interacts.

### 4.1 Environment and Habitat.

The term **habitat** is closely related to the concept of environment. Habitat is ecologically defined as the **sum total of all such condition of environment which influences the individual species or a community in that particular locality.**

The term habitat is more specific than environment as a whole. The **Preferred environment** of a plant is normally called its habitat. Plants living on land are termed to have terrestrial habitat, while those living in water have an **aquatic habitat.**

### 4.2 Environmental Factors

The environment comprises a number of factors interacting with one another and also acting upon vegetation. For convenience they can be broadly identified into two groups namely

**Physical factors** – providing **abiotic** environment and the **Living factors** – providing **biotic** environment. The abiotic environment includes physical forces such as light (Radiation), temperature, precipitation, humidity, soil, wind etc. and the biotic environment includes numerous living organisms which inhabit in the physical environment.

Environmental factors do not act in isolation from one another. As a matter of fact all the factors interact with one another to influence the organism. Further, all the environmental factors do not influence the plant equally.

### 4.3 Classification of Environmental / Ecological Factors

All the ecological factors with reference to a plant can be classified into six major groups.

1. Climatic factors - related to the aerial environment Like Radiation, Temperature, Precipitation & Wind
2. Edaphic factors - related to the soil conditions
3. Topographic factors - related to the form and surface behaviour of the earth.
4. Biotic factors - related to the activities of other plants and animals

5. Pyric factors - concerned with fire hazards.
6. Anthropic factors - concerned with the role played by man.

### 4.3.1 ENVIRONMENTAL VARIABLES: CLIMATIC FACTOR – RADIATION

All life on earth is supported by the stream of energy Radiated by the sun and flowing into the Ecosphere. The ecosphere receives solar radiation at wave lengths ranging from 290 nm to about 3000 nm. Radiation at shorter wavelengths (ultra- violet) is absorbed in the upper atmosphere by the ozone and oxygen in the air, the long wavelengths or infrared radiation is absorbed by water – vapour and carbon dioxide of the atmosphere. About 40-50% of the solar energy received falls in the spectral region 380-780 nm which we perceive as visible light.

Radiation is characterized by its wavelengths. It is composed of small packets of energy called quanta or photons. The energy in a single photon is inversely proportional to its wavelength. That means, shorter wavelengths possess highest energy.

**Ultraviolet – B radiation**

Global UV- radiation on the earth's surface fluctuates with changes in altitude, cloud cover, stratospheric ozone concentration and atmospheric turbidity. No appreciable UV- radiation below 295nm is received on the earth's surface due to absorption of UV- radiation by stratospheric ozone layer.

In the light of modern research and development in photo biological studies on UV- radiation (a component of extra terrestrial radiation) it is divided into different groups based on their wave lengths.

| | | |
|---|---|---|
| i) UV below 280 nm | - | UV- C radiation |
| ii) UV between 280-320 nm | - | UV- B radiation |
| iii) UV from 320-390 nm | - | UV- A radiation |

Of these three types, plants are much influenced by UV- B radiation. Some of the effects can be seen as:

- Cotton seedlings when exposed to UV- B radiation showed bronzing of cotyledons.
- Exposure to UV- B radiation reduces plant height, fresh weight, dry weight and ash content in soybean, groundnut and maize.
- $C_3$ plants showed significantly more reduction when compared to $C_4$ plants in which chlorophyll content was much reduced when exposed to U.V radiation.
- There was inhibition of several components of photosynthetic reactions.

- Hill reaction activity was reduced in oats and soybeans. Electron transport system became ineffective. Photo system – II was more inhibited when compared  Photosystem – I.
- When exposed to 72 hours of UV- B radiation, the double membrane of chloroplast was disrupted and vesicles are formed in stroma. In mitochondria less number of cristae was observed.
- The enzyme RuBP carboxylase activity was reduced in soybean ultimately affecting photosynthesis.
- Dark respiration was stimulated much. Protein content was reduced significantly.
- There was reduction in nodulation and nitrogen fixation in *Crotaloria juncea,* when exposed to UV- B radiation.

#### 4.3.1.1 Effect of Radiation on Plant Functions

Radiation effect on plant processes may be divided into three categories *viz.* photoenergetic effects, Photo cybernetic effects and photo destructive effects. All these effects are brought by Photo receptors (pigments) of the plants.

**a. Photo energetic Effects**

The energy provided by absorption serves to drive metabolic reactions in a manner directly dependent on the amount of quanta absorbed. These effects include the production of energy rich compounds (photosynthesis) or alteration of molecular structures (Photo-conversion).

The primary process of photosynthesis in green plants is driven by radiation in the range of 380 to 710nm. This Photo synthetically Active Radiation (PAR) (400-700)nm) plays an important role in plant ecology. The photoreceptors involved in photosynthesis are chlorophyll (with absorption maxima in the red and blue) and accessory plastid pigments (like carotenes and xanthophylls that absorb light in the blue and UV regions)

**b. Photo cybernetic Effects**

Absorption of radiation chemically alters the receptor substances and affects the control of metabolism, growth and development. Low intensities of radiation are sufficient to produce these effects. Some important photo cybernetic reactions are:

1. Photostimulation : Formation of chlorophyll from precursors.
2. Phototropism : Radiation in adjusting the direction of growth
3. Photoinduction : Triggering germination and flower formation
4. Photoperiodism :Rhythmic events in the life cycle with response to the relative length of day and night.

Light in two regions of the electro magnetic spectrum is effective Photo synthetically i.e– blue to ultraviolet and red to near infra – red.

Elongation and Phototropism are regulated by blue- light whereas most other processes depend on the phytochrome system. Phytochrome is Photo convertible: It occurs in two forms P-660 and P-730 depending on the red (620-680nm) or far-red (700-800nm) illumination.

**c. Photo destructive Effects**

They occur with extremely high intensity of radiation. The damage consists primarily of Photo oxidation of chloroplast pigments. Some of the sensitive plants to strong light are algae, some ferns and shade plants.

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**Lecture-5**

## ENVIRONMENTAL VARIABLES: CLIMATIC FACTORS : PRECIPITATION

Since all life requires water and water is unevenly distributed over the earth, its abundance or scarcity in the environment is reflected on the vegetation. About 73% of earth's surface is covered with water in the form of rivers, streams and oceans. The source of precipitation is the atmospheric water vapor. This source of atmosphere reaches the earth's surface through precipitation and the water from the earth's surface goes back to the atmosphere through evaporation and transpiration. This is a continuous and cyclic process termed as Hydrological Cycle or Water Cycle.

At a given time the amount of water in the atmosphere has been estimated to be only enough to provide a one inch rainfall for the whole world. It can meet only 10 day's supply. This limited supply means that the Hydrological cycle must be rapid and continuous.

According to Hutchinson (1957), world precipitation amounts to about $4.46 \times 10^{20}$ **Gallons** annually, of this amount about $0.99 \times 10^{20}$**G** falls on land surfaces and remaining $2.47 \times 10^{20}$ G falls on oceans and river surfaces.

### 5.1 Forms of Precipitation

Precipitation results as a consequence of cooling and condensation of water vapor at higher altitudes. The various forms of precipitation are rain, snow, hail, sleet, fog and dew.

#### Rain

Of the various forms of precipitation, rainfall is the main source of water for terrestrial plants.

#### Snow

White crystals of frozen water formed directly from water vapour of the air at temperature less than $0^0$C is known as snow. Snow may be injurious or beneficial to plants in a number of ways.

Its weight may cause physical injuries to the plants, especially when the snow fall is accompanied by wind. Plants ranging in size from small grasses to lofty pines are damaged by heavy snows. Glazing, which is the coating of leaves and stems by snow may cause damage by suffocation, accumulation of toxic materials, oxygen deficiency or by physical breaking.

The gradual melting of mountain snow feeds streams descending to the low lands during summer. Winter surveys of the depth and water content of snow in such regions helps in good forecast of the supply of irrigation water that is available in the following season.

**Hail**

It is a special type of precipitation during summer season in the form of small ice pieces. This is too infrequent and not a significant source of soil water. It is called a Hail-storm when it is accompanied by wind. It may cause considerable temporary damage to the aerial parts of plants.

Orchard crops like Mango during flowering and fruit setting damages severely by this hail storms.

**Sleet**

Frozen or partly frozen rain is called as sleet. This is not a frequent phenomenon and causes considerable damage to plants, especially in case of tender crops.

**Fog and Mist**

It is the visible vapor content of the atmosphere which is formed when the air is cooled near the surface of land. It is more frequent at higher relative humidity and occurs during winter. The moisture released by fog and mist are absorbed by the leaves thus, meets a substantial fraction of the water needs of plants in certain dry areas.

**Dew**

The moisture condensed upon the surfaces of cool bodies like grasses, usually at night, is called as dew. It is the main source of water for the ephemeral plants (which can complete their life cycle in a very short time like drought evading types) that grow in the deserts. Dew formation occurs normally during winter.

➢ Effect of precipitation on plant growth and development can be understood from the perspective of effect of water deficit and water logging on plant processes:

**5.1.2 Effect of water deficit on vegetation:**

- The health and survival of a plant depends on a proper water balance. Any degree of water imbalance will affect physiological activity, growth and reproduction of plants.
- Photosynthesis and related metabolic processes dependent on gas exchange are quickly impaired by water deficiency as the deficit induces the closure of stomatal aperture and thus stops $CO_2$ uptake. Carbohydrate synthesis is therefore suppressed and the growth potential is reduced.

- Imbalance between photosynthesis and respiration is seen with increased water loss. A net loss of reserves must occur if respiration exceeds Photosynthesis.
- Protein breakdown: Wilting causes proteolysis. Wilting causes degradation of proteins to amino acids particularly proline in high concentrations. proline is the only amino acid constantly present in large amounts in all the plant organs. The accumulated proline is involved in osmotic adjustment as a compatible solute and is also involved in detoxification of ammonia etc .
- Enzyme inactivation: The enzymes are inactivated under moisture stress. eg. Nitrate reductase show considerable decrease in corn seedlings when the leaf water potential decreased below -2 bars.
- Nucleic acid loss: Water stress causes reduction in RNA content and also decreases nucleic acid synthesis.
- Hormones: Under water stress accumulation of ABA was reported and this ABA is responsible for closure of stomata.
- Foliar symptoms of moisture stress are far more common .Wilting in leaves is the earliest readily visible expression of moisture stress. Leaves in a wilted state are relatively non-functional, and if wilting is prolonged and tissues remain desiccated, they will ultimately die.

**Blossom – end – rot** of tomato fruits is the classic example of a drought – related fruit disorder. It appears as a water – soaked spot at the stylar end of the fruit. The disease develops when plants have grown rapidly and luxuriantly during an early favorable season and then subjected to moisture stress.

### 5.1.3 Effect of water logging on Plant Processes

The normal mesophytic land plants must have oxygen for the liberation of energy required to maintain life processes. When the pore spaces of the soil are filled with water, the plant root suffocates. The immediate effect of suffocation is suppression of growth. Plants may survive brief periods of oxygen deficiency of even 0.5 per cent oxygen is available in the soil. However, plant roots need 2 to 8 per cent of $O_2$ for their optimum growth. Below this, leaves become chlorotic, growth ceases, no new roots develop, shoots die back and death is ensured. In addition to reducing the available oxygen, flooding may decrease transpiration over 90 per cent, limiting water absorption and photosynthesis.

Low soil oxygen is most damaging when soil or air temperatures are high. Sunflower plants grown under low oxygen levels had weak, stunted growth at 13 and $24^0$ but died if they were exposed to $34^0$ C. plants require less oxygen at low temperatures, they are able to endure low oxygen levels at low temperatures. But at higher temperatures, respiration is accelerated and the demand for oxygen is great.

There are several situations which give rise to excessive water. The poor drainage afforded by heavier soils is probably the most common, other reasons being heavy rain, run off or irrigation. But whatever be the reason for excessive water, the effect is much the same and depends on the sensitivity and tolerance of the species.

Apart from roots, the soil micro – organisms are greatly affected by poor aeration in waterlogged situations.

### 5.2 ENVIRONMENTAL VARIABLES: CLIMATIC FACTOR – TEMPERATURE

Although some heat originates from the interior (core) of the earth and another small increment originates from decomposition of organic matter, by far the greatest part of the energy available at the Earth surface is derived from the Sun by radiation. The localization of this heat source together with the movements of the earth, create great variations in the temperature phases of environment. The amount of heat received from the sun fluctuates owing to the momentary passing of clouds and to variations in daily, seasonal, annual and geological processes.

As the sun rises in the morning, the earth's surface beings to gain more heat than the heat lost by radiation so that, its temperature rises progressively and rapidly. After several hours a relatively high surface temperature is attained and radiation gains are approximately equaled by losses due to re-radiation and conduction. After the sun sets, the earth's warmed surface continues to give up its accumulated heat to the atmosphere.

#### 5.2.1 Cardinal Temperature

Temperature regulates all the chemical processes, many physical processes and biological processes. The metabolic processes of plants begin at a certain **minimum temperature** and increases with rise of temperature until they reach a peak at a temperature called the **Optimum temperature**. Further rise in temperature is accompanied by a fall in metabolic activity until it ceases at a temperature called the **maximum temperature**. The three temperature points *viz*, minimum, optimum and maximum temperatures are referred as Cardinal points or **Cardinal Temperature** For example.

| | **CARDINAL TEMPERATURES ($^0$C)** | | |
|---|---|---|---|
| | **Minimum** | **Optimum** | **Maximum** |
| Cool season cereals (Wheat, Barley, Oats) | 0-15 | 25-30 | 31-37 |
| Warm season cereals( Rice, Maize, Sorghum) | 15-18 | 31-37 | 44-50 |

**5.2.2 Effects of temperature on plant processes**

Temperature affects the rate of metabolic activities of plants. Cardinal Temperatures differ for different functions of the same plant. The processes influenced most strongly by temperature include chemical reactions, gas solubility, mineral absorption, and water uptake.

1) Plant development is largely a function of the cellular biochemical reactions. These reactions are controlled by the enzymes and the rate at which the enzymes act and the reactions proceed is a function of temperature. Ex: Photosynthesis is an important process which depends on enzymatic activity and is considered as a temperature- dependent reaction.

2) Temperature is the most important factor determining the solubility of gases in the plant cell. $CO_2$ and $O_2$ solubility are particularly influenced by temperature. Low temperatures facilitate solubility of these gases and large amounts can be held in the sap of the plant cells. **This suggests that low temperatures may favor $CO_2$ fixation and increase the carbohydrate reserves, which helps to protect plants against still lower temperatures**. Such high $CO_2$ concentrations at low temperature may also increase the acidity of the cell sap slightly and this could influence the availability of the plant nutrients.
3) Temperature directly influences the availability and absorption of mineral elements from the soil. In active absorption, the plants absorb essential mineral ions by expending energy which is temperature dependent. Prolonged low temperatures limit the available energy, and results in nutrient deficiencies. Furthermore, the tenacity with which soil particles cling to the mineral ions is regulated by temperature.
4) Temperatures influence the ability of the roots to absorb water. The viscosity of water doubles as temperatures drop from $25^0$ C to $0^0$ C, water is bound tightly to the soil and is absorbed by plants with extreme difficulty. Low temperatures can significantly limit water uptake particularly passive absorption which is strongly influenced by viscosity, even when water is abundant. Optimum absorption of water generally takes place above $30^0$C.

**5.2.3 Temperature injuries caused by high or low temperature stress are discussed below:**

When temperature rises above the maximum for growth, plant enters in to **Quiescent State**. When temperature drops below the minimum for growth, a plant becomes **Dormant**.

### 5.2.3.1 High Temperature Stress

Besides from its role in desiccation, and in bringing about an imbalance between respiration and Photosynthesis, high temperature can injure and kill protoplasm. Plants grown in temperate regions of the world are poorly adopted to withstand the stresses imposed by high temperatures and can rarely tolerate temperatures much above $35^0$C.

The principal adaptational features which protect plants against high temperature injury are:

1. A vertical orientation of leaf blades which always reduces the tissue temperatures at least $3^0$C below that of leaves turned at right angles to the sun's rays.
2. Whitish color of surfaces which reflects rays that would otherwise be absorbed and become heat energy.
3. A covering of dead hairs which shades living cells.
4. A thick corky bark which insulates the phloem and cambium.
5. Thinness of leaf blades, coupled with a high rate of transpiration, which prevents leaves, exposed to the sun from becoming more than $5^0$C warmer than air.
6. A low moisture content of the protoplasm and high carbohydrate content.

#### 5.2.3.1.1 Classification of plants Based on Heat- Resistance

The resistance is ordinarily taken as the temperature at which half of the plant samples are destroyed (this is called as temperature lethality $TL_{50}$). On the basis of heat resistance, plants may be categorized into the following three types:

**I. Heat Sensitive Species**

This group includes all species that are injured even at 30 to $45^0$C. Ex: Submerged vascular plants, soft-leaved land plants, tomato wilt virus.

**II. Relatively Heat - Tolerant Eukaryotes**

These plants are capable of developing resistance to heat. They can survive heating for half an hour at 50-$60^0$C. Ex: Plants of Sunny and dry habitats.

**III. Heat – tolerant Prokaryotes**

These plants can endure exceedingly high temperatures. These are equipped with especially resistant nucleic acids and proteins. Ex: Thermophilic Bacteria (with stands as mush as $90^0$C). Blue – green algae (as much as $75^0$C).

### 5.2.3.2 Low Temperature Stress

Low temperature injury occurs when a plant gives off more heat than it absorbs. The death by cold is the consequence primarily of disturbed nucleic acid and protein metabolism though changes in permeability of membranes and stoppage of Photosynthesis are also involved. Plants resistant to chilling above the freezing point are damaged by frost that is by ice formation in the tissues. Usually ice is formed not in the protoplasts (Intracellular ice formation) but rather in the intracellular spaces and in the cell walls (Free space or outer space). This sort of ice formation is called Inter cellular ice formation.

The sensitivity of plants to low temperatures, and the amount and severity of injury, depends to great extent on the physiological conditions of the plant. For example mineral nutrition, especially the nitrogen level has a particularly strong influence on low temperature tolerance. Tissues too high in nitrogen are soft, with moderate to low nitrogen content are harder and more tolerant of temperature extremes.

**Adaptation to low temperature stress**

The ability of plants to endure low temperature extremes varies widely among species. Certain plants of tropical affinity (Ex. Rice and Cotton) are injured by exposures to temperatures which are low but yet above the freezing point. Plants native to temperate climates can endure periods when the tissues are frozen solidly and the temperature drops to $-62^0$ C. the freezing points of plant sap, because of its solute content, usually lies several degrees below $0^0$C but certain plants (mostly cryptogams, and seeds can not be frozen at temperatures even-$270^0$ C and these are immune to low temperature injury.

A plant is not equally resistant to low temperatures at all stages of its life-cycle. Seeds and spores are generally the most resistant stages. All organs of the same plant are not necessarily equally resistant to low temperature at the same time. For example the ovule may be killed without apparent injury to the carpel.

#### 5.2.3.2.1 Classification based on Cold-Resistant

On the basis of the limits and the specific nature of cold resistance, one may distinguish three categories of plants:

1. **Chilling – Sensitive Plants:** this group includes all plants seriously damaged even at temperatures above the freezing point. Ex : Rice; cotton and cowpea.

2. **Freezing – Sensitive Plants :** These can tolerate low temperature but they are damaged as soon as ice beings to form in the cells. Ex: Valencia peanuts.
3. **Freezing – Tolerant Plants :** These plants survive extra cellular freezing and the associated withdrawal of water from the cells. Ex: Certain freshwater algae, Algae of tidal zones and Perennial land plants.

### 5.2.4 Concept of Heat Units:

Reaumer (1735) has introduced Heat Unit concept and stated that the sum of mean daily air temperature requirement by a species towards maturity is constant from year to year. Boussingault (1837) followed the same method and called the calculated heat unit requirement as Degree days.

Plant development is inhibited by a temperature below a certain level which is referred as Base temperature (Threshold temperature) this has to be subtracted from the daily mean temperatures before carrying out summation of growing degree days.

| Base temperatures for certain crops | |
|---|---|
| Rice | 10-15 $^{0}$ C |
| Wheat | 4 -5 $^{0}$ C |
| Maize | 8-10$^{0}$ C |

Of late, accumulated Growing degree days are used synonymously for heat units.

**Growing degree days:** This is the arithmetic accumulation of daily mean temperatures above certain threshold temperature.

$$\text{Growing degree day} = \sum \left( \frac{\text{Maximum temperature} + \text{Minimum temperature}}{2} \right) - \text{Base temperature}$$

During a crop season, number of days the crop is exposed to a daily mean temperature above the base temperature is calculated. When it is calculated every day it is called as growing degree day. Accumulation of such growing degree days during a crop season is called as Effective Heat units. For example accumulated heat units for Maize and Cotton in United States climatic conditions are calculated as 1600-1800(from planting to harvesting) and 1900 units respectively. These heat units help us to estimate the crop yield by modeling.

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**Lecture-6**

## ENVIRONMENTAL VARIABLES:CLIMATIC FACTORS :

### 6.1 EDAPHIC FACTORS

The factors of the environment that are related to the soil are called edaphic factors. The branch of science concerned with the study of soil formation, composition and classification of soil types is called pedology. Knowledge of fundamentals of this field is an absolute prerequisite to understand plant ecology.

Soil contains most of the mineral elements which are essential for plant growth. Deficiency of any one of these elements severely impairs plant growth. Besides, excess presence of these elements also causes serious problems. For example excess of Aluminium in acidic soils cause leaf yellowing, distorted root growth and reduced shoot growth.

**6.1.1** LIST OF EDAPHIC FACTORS

a) Soil Moisture

b) Soil Temperature

c) Soil Aeration

d) Soil reaction (PH)

e) Soil organisms

f) Soil nutrients

Marsden–Jones and Turrill (1945) reporting on a comprehensive project of the British ecological society, listed a number of effects of different soils on the plants. They are

1. Germination ability of seeds

2. Size and erectness of the plant

3. Woodiness of the stem

4. Depth of the root system

5. Pubescence on stems and leaves

6. Susceptibility to drought, frost and parasites

7. General vigour of the vegetative parts.

8. Number of flowers and date of flowering.

## 6.2 CLASSIFICATION OF PLANTS BASED ON SOIL TYPES

Plants growing in different types of soils exhibit variations in their physiological and morphological features. Based on the characters of soil Warming (1909) has classified the plants in to five groups: They are

1. Oxalophytes - Plants growing in acidic soils
2. Halophytes - Plants growing in saline soils
3. Psammophytes - Plants growing on Sandy soils
4. Lithophytes - Plants growing on rocks
5. Chasmophytes - Plants growing on rock crevices

### 6.2.1 OXALOPHYTES:

Oxalophytes are the plants that grow on acidic soils. The acidity in the soil develops due to chemical composition of parent materials, metabolism of soil microbes and accumulation of organic matter. In temperate climates soil acidity develops mainly due to accumulation of un decomposed organic matter. On acidic soils several *Pinaceae, Eriaceae,& Polytricum* species grow well. Roots of these plants are restricted in the upper acidic soil horizon.

### 6.2.2 HALOPHYTES:

Halophytes are those plants which grow on soils and in water- rich in salts. The non Halophytes such as Sugar beet and Alfalfa sometimes grow on saline soil and are known as facultative halophytes. In saline conditions water is usually not available owing to its high concentration and plants are unable to absorb water in these conditions. (The mechanisms for salt tolerance are discussed in the later part of this chapter)

The effect of dissolved salts on the plant is partly osmotic and partly chemical. Important adaptive features of plants growing on saline soils are as follows.

a) Plants grow chiefly on rainy season when soil solution has been diluted and salts move down below the root zone.

b) Germination and seedling establishment is mostly restricted to rainy season.

c) Plants are usually shallow rooted. Surface feeding roots are helpful in aeration, as the soil becomes water logged in the rainy season.

d) Most of the halophytes exhibit succulence.

The flora adapted to saline water is more diverse. The saline marshes of temperate region are dominated by herbaceous succulents while in tropics they shows a remarkable tree growth which are called as Mangrove forests.

The most important features of mangrove plants are as follows:

1. Leaves are succulent, highly cutinized and posses well developed palisade tissue.

2. They exhibit a vast network of prop roots which supports plants high above the water mark.

3. Presence of negatively geotropic pneumatophores- specialized organs for respiration are seen.

4. They exhibit vivipary (Seeds germinate inside the fruits while they are still on the mother plant)

### 6.2.3 PSAMMOPHYTES

Psammophytes are the plants adapted to sandy soils. Since the soil is made up of bigger soil particles, the water is not retained in the upper layers of soil but it trickles down to reach ground water table. Thus, most of the time the soils remain deficient in water and plants have to depend on dew and ground water for their requirement. Therefore, psammophytes have a well developed root system which enables them to procure water both from deeper layers of the soil as well as from upper soil horizon.

The plant community developed in such soils is very sparse and is mostly dominated by annual herbs, grasses and shrubs.

### 6.2.4 LITHOPHYTES:

Lithophytes are the plants grown on exposed rock surface. Plants which can withstand high degree of desiccation grow on such surfaces. Lithophytes have the capacity to utilize the atmospheric humidity as a source of water.

Ex.Lichens and Selaginella

### 6.2.5 CHASMOPHYTES:

Chasmpophytes are the plants which can grow on rock crevices. These are grown slightly on a better condition of soil moisture. Soil in rock crevices is made up of gravel and coarse sand with low organic matter content. Plants growing in such habitats are mainly surface feeders and their roots are exposed to soil surface.

## 6.3 HALOPHYTES AND SALT STRESS TOLERANCE MECHANISMS

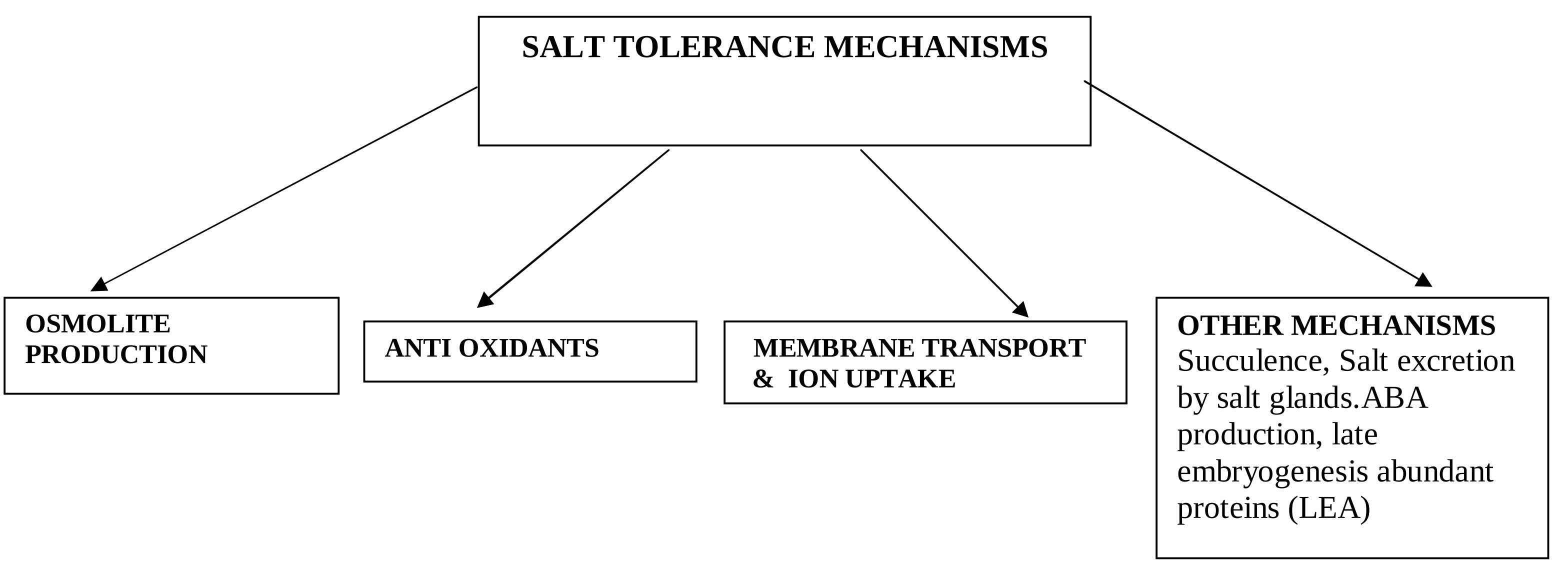
Salt affected soils contain excess soluble salts in the root zone of crop plants, which adversely affects their growth and yield. In India they are estimated to cover about **7 Million ha** area.

Plants are classified as **glycophytes or halophytes** according to their capacity to grow on salt medium. Most plants are glycophytes and cannot tolerate salt stress because-

- High salt concentration (chlorides & sulphates ($Cl^-$ &$SO_4^{--}$ ) of Na and Mg in case of saline soils) decrease the osmotic potential of the soil solution creating a water stress in plants. This is known as **physiological drought** (i.e. water is available around the root zone but plant cannot take up this water because of the highly concentrated soil solution around the root)
- Secondly, they cause severe ion toxicity.
- Finally, the interactions of salts with mineral nutrition may result in nutrient imbalances and deficiencies.
- **Alkali soils** are rich in Carbonates and Bicarbonates which makes the physical condition of the soil so poor. For example, seed germination is difficult in these soils because of the Crust formation by the salts.

**Relative tolerance of crops to salts:**

| Tolerant | Medium tolerance | Sensitive |
|---|---|---|
| Barley, Cotton, Sugar beet, Tobacco. | Wheat, Rice, Oats, Maize Sorghum, Potato | Legumes (Mung, Urd, Gram), Beans, Groundnut, Alfalfa |



### 6.3.1 OSMOLITE PRODUCTION:

High salt concentration or decreased osmotic potential outside the root environment does not allow the root to absorb water. It not only does impair the uptake of water but also affect the nutrient uptake. One of the strategies of the plant to avoid this situation is to produce osmolites. They help in increasing the concentration of the cell sap. Thus, the osmotic potential gets adjusted with the outside environment. There are different groups of osmolites like

| **Carbohydrates** | **Nitrogenous compounds** | **Organic acids** |
|---|---|---|
| Ex: Sucrose, Mannitol, Sorbitol, Pinitol | Ex: Proline, Glycine betaine | Ex: Oxalate,Malate Glutamate, Aspartate |

### 6.3.2 ANTIOXIDANTS:

Salt stress like any other abiotic stress leads to production of reactive oxygen species (ROS) like

**Singlet oxygen ($^1O_2$), Superoxide radical ( $O_2^{-\cdot}$ )**

**Hydrogen Peroxide ( $H_2O_2$), Hydroxyl radical ( $OH^{\cdot}$ ).**

Antioxidants are mostly enzymes like Super oxide dismutase (SOD), Ascorbate Peroxidase (APOX), Glutathione Reductase (GR) and Catalase (CAT). These enzymes help in scavenging the potentially hazardous ROS.

### 6.3.3 Membrane transport and ion uptake

The ability of plant cells to maintain low cytosolic sodium concentrations is an essential process for halophytes .Plant cells respond to this situation by increasing sodium efflux (sending out sodium) at the plasma membrane. $Na^+$ is exchanged for $H^+$ ions across the membrane by **$Na^+/H^+$ antiporters.** Some times sodium ions are accumulated in the vacuole (**Ion compartmentalization),** in which tonoplast permeability plays an important role.

### 6.3.4 Regulation of Ion homeostasis:

Regulation of sodium, chloride, and potassium uptake is almost certainly vital in the adaptation of plants to saline soils. Salt tolerance requires not only the adaptation to sodium toxicity, but also the acquisition of potassium (an essential nutrient) whose uptake is affected by high external sodium concentration, due to the chemical similarity of the two ions. Therefore, potassium transport systems involving good selectivity of potassium over sodium can also be considered an important salt tolerance determinant.

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**Lecture-7**

## ENVIRONMENTAL VARIABLES: CLIMATIC FACTORS:

### 7.1 <u>PHYSIOGRAPHIC FACTORS</u>

The factors related to the form and surface behavior of the earth constitute physiographic factors or topographic factors.

Topography affects the growth of plants in two ways

a) They bring about local variations in climatic conditions

b) They can modify the edaphic factors.

The topographic factors include

1. Altitude of the place
2. Steepness of the slope
3. Exposure of the slope to light and wind
4. Direction of the mountain chains

#### 7.1.1 Altitude Of The Place:

Altitude refers to the position of the land surface to the mean sea level (MSL). The continuous increase in altitude and its effect on vegetation can be best observed on the mountains. Increase in altitude is usually associated with climatic changes, namely

- Decrease in temperature
- Increase in precipitation
- Increase in wind velocity
- Increase in humidity

Amount of total solar energy absorbed at higher altitudes is more. However, increased absorption of heat is not able to raise the temperature of the air because of strong winds and increase in precipitation at higher altitudes. As we ascend the mountains, due to changes in temperature, amount of precipitation etc, we can observe a definite pattern of vegetation. A similar sequence of change in vegetation can be seen when we move from equator to poles.

#### 7.1.2 Steepness of the slope:

The slope of a mountain is another feature of topography which affects the nature of vegetation.

Steep slope causes swift runoff of water after rain. This will decrease the moisture content of the soil and the soil becomes untenable due to erosion.

The water table on the slopes is also very low. Further, in the adjacent valleys the water table is nearer to the soil level and therefore they have luxuriant vegetation. There is no possibility for accumulation of humus on slopes and thus difficult for plants to establish on slopes. It is because of this reason absence of higher plants has become a characteristic feature of steep slopes.

The only possibility for cultivation of crops in steep slopes is through terrace farming. (Small terrace like flat fields reduces the force of the water flow)

### 7.1.3 Exposure of the slope to light and wind:

A mountain slope exposed to weak intensity of light and strong dry winds has xerophytic vegetation.

Ex. The vegetation of northern slopes of the Himalayas

The slope exposed to direct sunlight and humid winds has luxurious mesophytic vegetation.

Ex. The vegetation of Southern slopes of the Himalayas

### 7.1.4 Direction of mountain chains:

The direction of mountain chains has a tremendous effect on the climate of a region. If the mountain chain lies in the path of winds with full of water vapour, there happens a heavy rain fall on the wind striking side of the mountain and results in very luxuriant vegetation.

For example: Based on the data of a recent few decades, **Mawsynram** located in the state of Meghalaya appears to be the **wettest place in the world** or the place with the highest average annual rainfall.

Reasons for this are as follows.

During the monsoon season, warm moist winds from the Bay of Bengal move towards Northern part of the country. When these winds drift towards north eastern side they are forced to converge in the narrower zone over the Khasi Hills of Assam and Meghalaya. Thus moisture is concentrated in this area. The alignment of the Khasi Hills (east to west) places them directly in the path of the airflow from the Bay of Bengal, producing a significant uplift of moisture laden winds, their cooling and condensation. On the other hand similar winds moving from the Arabian Sea blow over a part of Rajasthan without condensing into rain drops because there is no mountain chain in the path of the wind.

## 7.2 EFFECT OF WIND ON PHYSIOLOGICAL PROCESSES OF PLANTS

**Definition:** air in motion is generally referred to as wind

**Velocity of wind at a particular place depends on**

1. Geographical situation 2. Topography (form and surface behavior of Earth)

3. Distance from sea shore 4. Flat plains and vegetation cover

Air moves from a region of high pressure to the one of low pressure. Pressure differences are caused basically by unequal heating of the atmosphere, the equatorial region receiving more heat than regions further south and north. In general this results in a movement of air from the poles (High pressure) towards the equator (low pressure).Thus, winds correct the imbalance of solar energy and prevents a cumulative excess of energy in the tropics and a deficit in polar regions.

**7.2.1 Effects of wind on vegetation:** Wind has both positive and negative effects on plants.

- Winds help in transporting of water vapor to inland areas from large water bodies. They play a crucial role in hydrological cycle.
- Transporting of pollen and seed dissemination is an important ecological function performed by winds.
- Winds have a powerful effect on the humidity of atmosphere. Layers of humid air adjacent to plant leaf surfaces are removed by wind. This tends to keep relative humidity low and to increase transpiration rate. The velocity of wind increases with height so trees may suffer more from drying effects than do herbaceous plants.
- Unidirectional strong wind causes complete distortion of general shape of the plant and its branches by killing the buds and twigs.
- Plants like Rice, Maize and Sugarcane fall flat on the ground due to lodging caused by strong winds. Single trees or a group of trees which are uprooted in forests by strong winds are known as ‘wind throws’ or ‘wind falls’.
- Winds carrying coarse sand particles may tear off the delicate surface of the leaf .It allows easy entry of pathogens.
- Along the sea coasts strong winds carry salts from the near by seas and deposit them on plants which is called as ‘salt spray’
- Plants growing under the influences of dry winds causes’ desiccation. This will decrease the turgidity of the cells and their size is reduced. Plants exposed to such unidirectional winds are usually dwarfed in their stature.
- Much damage to crops is caused by hot dry winds during the time of flowering. The decrease in flower set is because of the upset caused by hot dry winds in the internal water balance of the plants.
- Soil erosion is aggravated by winds in dry regions and areas with extended periods of drought.

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**Lecture-8**

## ENVIRONMENTAL VARIABLES: CLIMATIC FACTORS : PYRIC FACTORS

The environmental factors concerned with the effect of fire on vegetation are called as pyric factors.

### 8.1 Sources of fires

**I) Natural fires**

1. Lightening
2. Constant rubbing of branches

(Branches having inflammable resins Ex. Pinus)

3. Heat generated by the activities of saprophytic bacteria.

**II) Artificial fires**

1. To clear the forests for habitation and agriculture (Shifting cultivation)

### 8.2 Types of fires:

| S No. | Type of fire | Reasons for fire & matter involved | Extent of damage caused |
|---|---|---|---|
| 1 | Ground fires | Occurs when accumulated humus and debris catches fire. They show Smoldering effect (burn and smoke without flame) | Destroys all plants that are rooted within the debris |
| 2 | Surface fires | When dried twigs and fallen leaves catch fires. | Rapidly spreads over the forest floor Kills and scorches ground flora and bases of forest trees |
| 3 | Crown fires | When tree tops of dense forests catches fire it leads to crown fires. | Spreads easily from one crown to another. Engulfs the entire forest, cause huge flames and consume entire tree from top to bottom |

### 8.3 Effects of fire on vegetation and environment:

**Negative effects:**

1. Destruction of humus and organic matter. It can also disrupt Nitrogen cycle.
2. Destroys seeds and seedlings of many plant species
3. Damages surface layer of the soil and its fertility.
4. Changes the composition of forest species.
   a) Sciophytes are displaced by heliophytes
   b) Fire sensitive species are replaced by fire tolerant species.
5. Fire exerts stimulating effect on growth and seed production ability of certain weed species like *Cynodon dactylon* .
6. Fire leaves wounds and large scars on the trunks of woody trees which facilitate easy entry of parasitic bacteria and fungi.

**Positive effects:**

1. With fires, immediate supply of potash increases.
2. In certain cases harmful surface layer (highly acidic raw humus) may be eliminated. This practice helps in increasing the PH value of the soil.
3. Burning of undesirable debris eliminates certain harmful pathogens.
4. Well planned burning is taken up to clear old forests and to take up new plantations.

**Plant adaptations to fires**

- Seeds of certain species are fire-resistant and easily escape fire injury Ex.Pinus
- High moisture content in the leaves of coniferous plants prevents fire to some extent.
- Certain plants like Eucalyptus possess auxiliary buds and ligno tubers. They are dormant during fires. Once the fire puts off they helps in producing new growth.
- Certain plants develop thick bark and cork layers to escape from fires.

## 8.4 Management of fires and rejuvenation of crops:

Burning practiced by farmers and foresters can also be considered beneficial in certain instances like

- Controlled burning is practiced to convert forest and field to agricultural uses
- Agricultural burns, such as in the case of sugarcane
- To improve pastures
- controlled burning is used as a part of forest management

**Burning crop residues:** Burning crop residue in the respective fields is a common phenomenon as preparatory measure of fields before monsoon rains and otherwise too. When crop residue is burnt in a controlled manner it turns into ash. Ash has its value especially in improving the pH of the acidic soils. It also adds potassium to the soil. How ever, burning practice leads to loss of valuable organic matter. **Rejuvenation of plants :** Forest fires help the seeds and cones of certain plant species. These cones which are coated with resins releases seeds only when they are exposed to fires.

Ex. Pinus plant has serotinus cones completely covered with thick resin. These seeds remain dormant even for a period of 75 years. This seeds get a chance to germinate only when they are exposed to fires.

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**Lecture-9**

## Environmental variables: BIOTIC FACTORS

The effects of the activities of living organisms constitute biotic factors. These activities in a community include interactions among plants, plants and local animals, plants and microorganisms and above all, influence of man on plants.

The plants ability to live and grow depends not only on the physical factors of the environment but also on other organisms which can usually modify the physical environment. Physical factors are usually the governing forces of environment but some biotic influences are truly direct.

The plants association with other organisms is either social or nutritional. Plants provide Niche (dwelling) for the animals, and the animals feed upon the plants, pollinate them, disperse them or destroy them. Plants also interact with each other competing for space, water and mineral nutrients of the soil.

Some of the important biotic factors are herbivores( grazing effect), symbiosis, insectivorous plants, epiphyte, parasites and mycorrizha.

### 9.1 GRAZING EFFECT:

Grazing and browsing (feeding on leaves and shoots of plants) by herbivorous animals has a profound influence on the soil and vegetation of an area. Uncontrolled grazing by animals like goats, sheep, cows, buffaloes, deer, camels, elephants etc has caused destruction of herbaceous and woody plants in the past.

In the Himalayas herds of cattle, goats and sheep have destroyed the alpine meadows completely. Seed eating animals may destroy certain species and displace them completely. In pastures the removal of grass often leads to the growth of thorny weeds.

### 9.2 SYMBIOSIS:

The association of two organisms for mutual benefit is called symbiosis and the organisms involved in such association are called symbionts. Some of the best examples for symbiosis can be seen from the following associations of living organisms

**9.2.1 Lichens:** lichen is composed of two different plants living in a very close association. One is the Blue green algae, a producer that makes food by photosynthesis and the other is a fungus, a consumer that obtains food from algae. These lichens are found growing on rocks or on the bark of trees. Without fungus the algae cannot survive because the fungus protects the tiny alga from drying out.

### 9.2.2 Rhizobium and leguminous roots:

Leguminous plants (Peanut, pea, Lucerne, soybean, clover, alfalfa etc.) by themselves do not have the ability to fix $N_2$. However, legume nodules containing viable rhizobium bacteria fixes $N_2$ in a Symbiotic way. In the symbiotic association the bacterium obtains carbon containing substances from the host and the host obtains fixed nitrogen through the agency of bacterium. Thus it is mutually beneficial to both organisms.

The following points explains the fine symbiosis between these organisms at every step in the process of $N_2$ fixation:

1) Host plant (legumes)produces Lectins, a specific group of proteins which interact with the carbohydrates (glycoproteins)found in the capsule of bacteria. This is a crucial factor for the bacterium to recognize its correct host plant.

2) In the processes of nodule formation, host plant releases tryptophan in to the soil which is taken up by bacteria (rhizobium)and metabolises it in to IAA.This IAA helps for growth and multiplication of root cells.

3) Initial infection of rhizobial cells occurs in root hairs, which undergo characteristic curling. After a series of cell divisions and multiplications root nodules are formed in the cortical cells of the host. Bacterial cells inside infected host cells (cortical cells) multiply rapidly and are transformed in to swollen forms called Bacteroids.

4) Bacteroids carry on the aerobic respiration and require $O_2$.But the enzyme system that fixes $N_2$ in bacteriods is very sensitive to $O_2$.Excess $O_2$ invivo inhibits Nitrogen fixation. This problem of bacteroids is solved by its host plant by producing a reddish protein called leghaemoglobin.

Leghaemoglobin delivers $O_2$ to bacteroids at concentrations necessary for their aerobic respiration but harmless to their $N_2$ fixing enzyme system.

Thus at each step a fine cooperation is found in the symbiotic relationship of legumes and Rhizobium.

### 9.2.3 Mycorrizha

Mycorrhizal fungi are species of fungi that intimately associate with plant roots forming a symbiotic relationship. Plants provide sugars and other organic substances to the fungi where as fungi helps the plant in mineral nutrition and water uptake.

**Advantages of mycorrhizal symbiosis**:

- Helps in uptake of water.
- Helps in mineral nutrition particularly in Phosphorus uptake. In some cases increased uptake of Zn and Cu has also been reported.

- This symbiotic association helps the plant to resist root rot and color rot diseases.
- It is also claimed to be helpful in release of growth hormones like GA and Auxin.

There are three major groups of mycorrhiza *viz.,*Ecto mycorrhiza, Endo mycorrhiza and Ecto-endo mycorrhiza. Out of which, first two groups are important in Agriculture and Horticulture.

### 9.3 INSECTIVOROUS BEHAVIOR:

Insectivorous plants are partly autotrophic and partly heterotrophic. They can manufacture carbohydrates by themselves but are Incapable of synthesizing proteins. The soil in which they grow is waterlogged, swampy and deficient in nitrogenous compounds. They supplement their requirement of Nitrogenous food by capturing and digesting insects. The leaves of these plants are modified to trap the insects.

E.g., Nepenthes (Pitcher plant), Utricularia (Bladderwort)

### 9.4 PARASITISM:

Parasites obtain nutrition from living plants.

The parasites produce roots called **haustoria** which penetrate in to the host plant tissue. They make connections with the conducting elements of the host.

Common angiospermic parasites include

| S No. | Nature of Parasitism | Name of the angiospermic Parasite | Host plant part | Crop |
|---|---|---|---|---|
| 1 | Total or complete parasites (depend for both water & food) | *Orabanche cernua*<br>*Striga parasitica*<br>*Cuscuta reflexa* | Roots<br>Roots<br>Stems | Brinjal and tobacco<br>Sorghum and sugarcane<br>Stems of many plants Ex.Blackgram |
| 2 | Partial parasites (derive water and minerals from host& make their own food material) | *Loranthus Longiflorus* | Stems | Neem & guava |

## 9.5 ANTHROPIC FACTORS

The factors related to the role played by man are called Anthropic factors.

Various activities of human beings considerably affect the distribution of plants and their survival.

Some of them are outlined here

**9.5.1 Deforestation:** Excessive and indiscriminate cutting and felling of the trees for the purpose of firewood, timber, house building and clearing the land for cultivation purpose has completely changed the vegetation of different places. These activities affected the ecological balance and are responsible for vast variations in climatic situations of the affected regions.

Recurrence of heavy floods in Ganga and Brahmaputra plains is mainly due to forest clearing during second world war for improving communications and military installations along Himalayan frontiers.

**9.5.2 Afforsetation:** To check the soil erosion, loss of fertility of soil and spread of sandy tracts in the plains the forest department has launched a drive to erect new forests .This process of raising forests in hither to barren and unproductive lands is called as afforestation.

**9.5.3 Reforestation:** This is referred to raising of forests on a forest land after the forest is cleared for timber and other purposes.

### 9.5.4 INDUSTRIALISATION

Unplanned and un-scientific method of industrialization has caused lot of disturbance to the natural ecosystems. Persistent disturbance to natural ecosystems may have pronounced and prolonged effects especially with regard to the toxic industrial chemicals.

### 9.5.5 CHANGE OF CROPPING PATTERNS:

Raising crops on virgin lands and after some time when they become less productive, shifting to new areas of virgin lands is referred to as shifting cultivation.

Through shifting cultivation man has brought forth large scale changes in vegetation patterns especially in the fragile ecosystems along the hills and savannahs.

Instead of changing the field every time, It is always better to follow crop rotation i.e raising different crops in the same field in a sequential order For example: legume crops after cereals, Shallow rooted crops after deep rooted crops.

### 9.5.6 INTRODUCTION OF NEW PLANT SPECIES:

During his migration and travel from one region to other man carried the seeds and saplings of useful plants, medicinal plants, fibre yielding plants and other industrially important plants. This practice has led to the spread of these useful plants to many regions of the world. In this process knowingly or unknowingly, man has also introduced many weed species, new diseases and pests in to new areas.

Through breeding programme the plant breeders produce new varieties of crops with different environmental requirements. Though this new varieties enhanced the productivity of various crops, their large scale cultivation in varying climatic situations posed many ecological problems. One such issue of current importance in India is introduction of transgenic food crops like Bt.Brinjal, Bt.Potato.etc.

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**Lecture:10**

# COMPETITION

The word “competition” denotes a striving for the same thing. In ecological terms competition is a process of interaction when two or more individuals/ Plants /organisms make simultaneous demand on a type of resource or quality of resource, in insufficient supply, to meet the growing needs.

Competition influences the ability of an individual to survive and reproduce. It results in reduced survival potential or death of both the individuals. Such interaction may involve direct contact between the affected individuals (direct competition), or it may be mediated through the environment (indirect competition). Hence, it influences the ability of population to maintain itself or to increase with time.

Plants in agriculture and forests compete for light, space and nutrients when supply and availability of resource is inadequate. In a struggle for existence plant communities modify, change or regulate their physical environment within certain limits through competition.

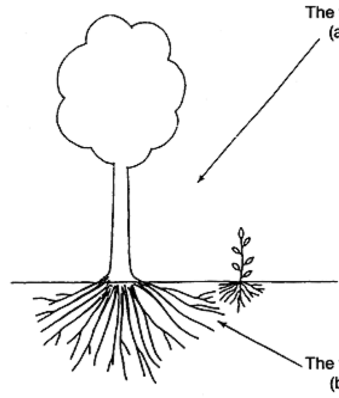
## 10.1 ECOLOGICAL SUCCESSION:

One of the most dramatic and important consequences of biological regulation in a plant community as a whole is the phenomenon of “ Ecological Succession” . When a cultivated land is abandoned in the eastern part of North America, for example, the forest that originally occupied the site returns only after the series of temporary communities have prepared the way. The successive stages may be entirely different in structure and function from the forest that eventually develops on the site.

Ecological succession, then, may be defined in terms of the following three parameters: (1) It is the orderly process of community change, (2) It results in the modification of physical environment by the community (3) It culminates in the establishment of a suitable ecosystem as is biologically possible.

## 10.2 DOMINANCE AND SUB - ORDINATION.

Competition exists when plants meet each other on more or less in equal terms. However, if it is not on equal terms- such as in the case of oak tree and a shade loving plant growing in its shade, the interaction between such plants is referred to as “Dominance” and “sub-ordination”. The distinction between competition and dominance is illustrated by development of secondary forest in a site (cleared by forest fire or deforestation). All the individuals (pioneers as they are called) compete with each other first; with the growth of the shrubs they become dominant over herbs and are in turn dominated by trees. Herbs or shrubs still compete with respective counterparts. Within the dominant tree layer, individuals compete with one another in the same higher layer.




**10.3 NATURE AND EFFECTS OF COMPETITION:**

The importance of competition both in development of natural vegetation and in crop production is so great that it has received much attention and very well studied. When seedlings/ plants especially of the same species are closely spaced, competition begins almost immediately. As the plants grow, it increases with density, stage of plant growth and shortage of needed resources.

Competition has two types of effects on the competing individuals :

1. Short term and 2. Long-term

**1. SHORT-TERM OR ECOLOGICAL EFFECTS**

Some of the short term effects that are important in a population are poor establishment, reduced growth rate and poor reproduction resulting in low dry matter production and grain/seed yields.

**2. LONG TERM OR EVOLUTIONARY EFFECTS**

The long term effects lead to succession wherein less suitable species are totally eliminated from the habitat itself.

**10.4 STRATIFICATION**

Stratification is the occurrence of plants in different strata (Stories or tiers of layers) at different heights or levels in a stand of plant community. It is a way of vertical distribution of plants. Both the above ground parts as well as underground parts show stratification. Some of the contributory causes for stratification are that the life forms such as trees, shrubs, herbs, and mosses (also bryophytes, lichens) differ in their requirements and ecological amplitude. Therefore, they grow at various levels (in a community) which differ in light intensity, temperature, humidity and other factors.

The stratification of vegetation facilitates a fuller and better utilization of environmental resources. It minimizes competition among plants of a stand.

These concepts are used in agriculture to make effective and economic use of the arial space within crops especially in plantation crops.

**(A) Stratification of aerial parts**

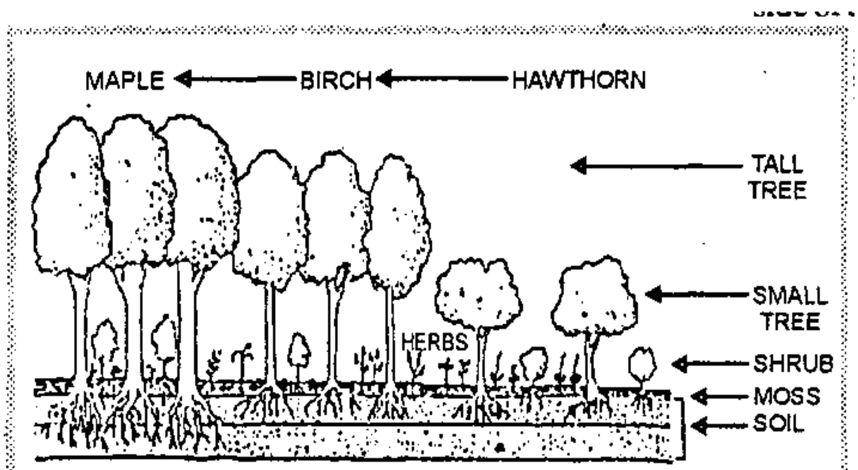
The number of strata above ground varies with the kind of plant community. In a forest, the number of strata is more. It is common to recognize a tree layer, a shrub layer, an herb (i.e., a field) layer and a bryophyte-lichen (the bottom – ground layer).

Stratification is well developed in tropical rain forests where 7-8 strata may be well recognized; here the trees and shrubs are divided into two or three tiers of tall and short herbs. Each stratum has an environmental or habitat which differs from that of others. But in grasslands strata are few.

**(B) Stratification of subterranean parts**

Roots in the soil also show stratification so that competition between species is minimized and the resources available are more completely utilized. For example, in a forest the roots of herbs occupy the surface layer of the soil, that of shrubs root a little deeper and roots of trees grow very deep into the soil.

In agriculture, successful inter-cropping is based partly on root stratification, when groundnut and red gram are grown together in distinct rows (7:1), the roots of groundnut grow up to certain depth in the soil while red gram roots grow still deeper.



Stratification in a forest community.

**10.5 TYPES OF COMPETITION**

Three types of competitions are recognized in plant communities:

1. Inter- specific competition
2. Intra- specific competition and
3. Intra- plant competition

**10.5.1 Inter-specific competition**

Any interaction between two or more plant species adapted to same or similar niche affecting their growth and their survival is called inter-specific competition. In general it is more likely to be severe between closely related forms such as grasses with grass; than between those that are distant forms such as grass with dicots.

In nature, inter-Specific competition is common, the potential outcome being a reduction in number and size of the characters of individual, or in severity total disappearance of one or more species. Greater the difference between the species, in one or all the characters (root, leaf and stem) the less severe the competition. For instance, a deep rooted wild rose/rose plant does not compete with the shallow rooted grass.

In agricultural crops, in inter-cropped situations, crops are selected in such a manner, that there is no competition in component crops. For example, groundnut and red gram grown in 7:1 ratio, the crops differ in their height, branching, date of maturity and other physiological characteristics distantly. Hence, component crops would have the maximum advantage to exploit the resources from the environment and achieve the production potential and grain/ seed yield.

Weeds are known to compete effectively with the crop plants due to their vigorous nature in exploiting resources and better adaptability in limiting situations. If they are left un checked they can reduce crop yields.

**10.5.2 Intra-specific competition**

Competition between the members of the same species which adversely affect their growth and survival is intra-specific competition. In nature, this type of competition is not common because the vegetation consists of different species. However in situations, where the population comprises of the same species such as aquatic vegetation, agricultural lands where monoculture crops such as rice , wheat, jowar and plantations in forestry, there this type of intra-specific competition exists.

In such situations, population growth depends necessarily on density. But with appropriate spacing, it is possible to obtain minimum intra-specific competition. The total yield of these crops with increase in population per hectare maybe higher, but the size of both vegetative parts and fruits is reduced. Example: carrots, Onions, Cabbage and Cauliflower.

Intra- specific competition in grasses/ monocotyledons is very similar; where under higher density that plants grow erect due to competition for light with thin stem while widely (optimum) spaced plants grow producing more number of effective tillers. Crowded plants exhibits spindling, yellowish, nitrogen starved symptoms while optimum spaced plants have green foliage and shorter plants with good tillering.

### 10.5.3 Intra – Plant competition

Competition operating within the plant between different organs or parts or between similar parts for resources such as water, nutrients, photosynthates etc. is known as intra-plant competition. This type of competition within the plant may occur between:

1. Root and shoot
2. Leaves of different ages
3. The developing seeds

Young and developing fruits in a plant are strong sinks as they are more competitive than matured parts. However, environmental conditions interact with the stage of plant growth, size and number of plant parts, availability and mobilization of photosynthates to characterize the intra- plant competition.

The best example, is the grain set in cereals. In an inflorescence competition exists between basal spikelets and upper spikelets and upper florets within the spike let. Intensity of inter – grain competition within the spikelet during grain set and grain growth phase is an important factor that alters source- sink relationship. Increased number of grains per spikelet/panicle and individual grain weight depends upon the intensity of competition and on the sink drawing ability.

With the backdrop of nature and types of competition that exists in plant communities certain terms are important in cultivation of crops in agriculture.

## 10.6 MONOCULTURE:

Continuous cropping of same crop species in the same piece of land year after year or season after season is called as monoculture

Example: rice, wheat, Plantations in forest etc.

Plants with more sensitivity to inter-specific competition will show their best growth in monoculture, Here the time of onset of competition and intensity is linked to density of population which determines the inter- plant and intra-plant competition which in turn determine the final grain yield.

## 10.7 POLYCULTURE:

Cultivation of different species of crops in the same piece of land in a year either in a sequence or simultaneously is called as polyculture. Example (a) Rice followed by a pulse or groundnut (b) Groundnut and red gram grown simultaneously in inter cropped situation.

The species with minimum inter- specific competition show better growth in polyculture.

## 10.8 SHIFT CULTIVATION:

It is a farming system in which the land is cleared and cultivated for few seasons or years and that land is abandoned afterwards. This is because of exhaustion of soil nutrients; build up of weeds and pest populations.

It is always better to cultivate more number of crops in the same piece of land (eg.polyculture) rather than shifting the site of cultivation every time which makes the soil exhausted.

## 10.9 MULTISTORIED CROPPING SYSTEMS:

The concept of stratification is made use in developing multistoried cropping systems which allows better use of solar energy and soil fertility and increase the yield of crops which do not tolerate full sunlight Example : Cocoa, Cinnamon, Betel vine etc.

It is a system where crops with different stature and rooting habits are grouped to form compatible combinations so as to enable efficient light interception and utilization at different vertical intervals and facilitate exploitation of mineral resources at different layers.

One such combination is Coconut + Pepper + Cocoa or Cinnamon+ Pineapple is practiced in Kerala. Here, coconut is spaced 7.5 m apart; the black pepper is planted at the base of coconut, cocoa-cinnamon and pineapple in the interspaces between coconut trees.

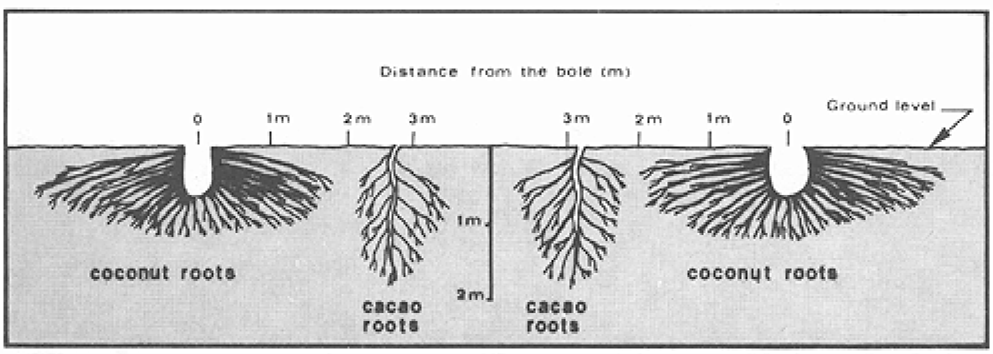
The pineapple which grows to a height of about 1 m forms the first ground layer; Cocoa-cinnamon with its pruned canopy grows to a height of about 3.0 m on coconut trunk and forms the second layer; The black pepper, the growth of which is restricted to about 6-8 m forms the third layer; coconut which grows to 10-30 m (tall form) occupies the top layer. Rooting characters tics of the component crops in the multistoried system or mutually exclusive horizontally. Roots of cocoa and cinnamon have tapering root systems with relatively lesser lateral spread; do not offer any effective competition with the roots of coconut palm.

**OTHER EXAMPLES:**

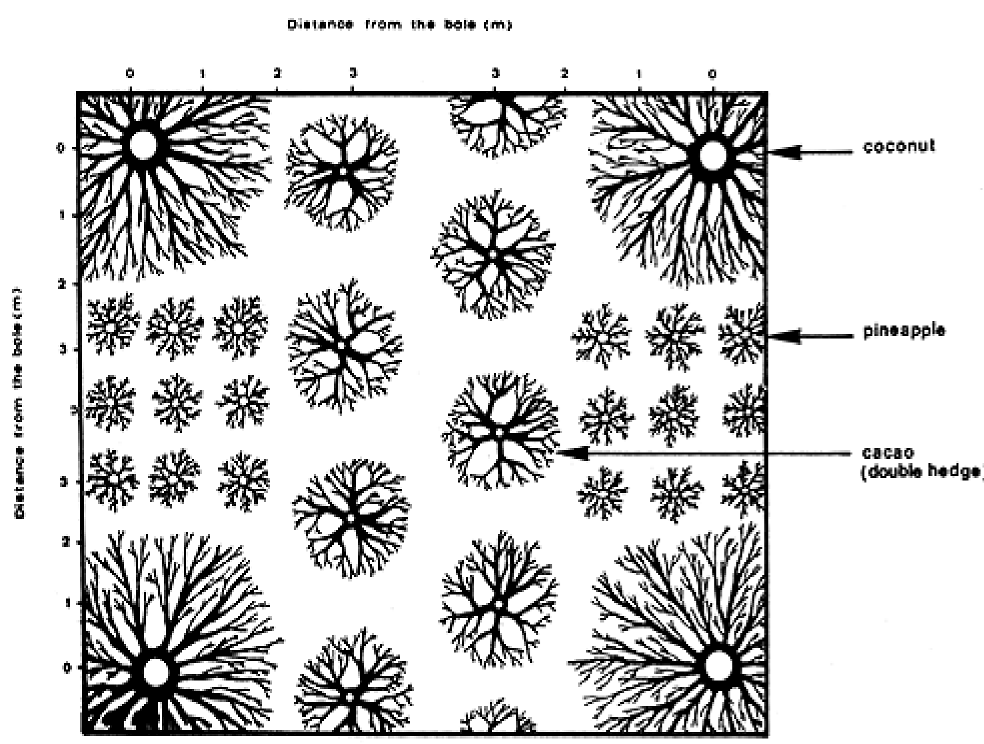
A) Coconut + Pepper + Rice + Cocoa : in Philippines

B) Rice + Cassava + Banana + Beans : South America

**Multistoried cropping**




**Stratification of roots at varying depths**




**Spatial distribution of roots**

## 10.10 MUTUAL SHADING

As plants grow in a community, leaves developing in upper positions normally cast their shadow on the lower ones. Hence, in a crop canopy there is mutual shading normally.

In forest canopies light reaching the ground is very much reduced. Plant/tree species adapted to shade will grow, otherwise will be eliminated in course of time. Mutual shading in a community is responsible for change in species composition and the life forms of constituent plants. Partial shade cause succulence, trees grow slender and straight, their height being very great in relation to the diameter.

In certain agricultural crops, certain amount of competition under the influence of mutual shading is desirable. For example, (1) In fibrous crop Corchorus sp. The mutual shade created by increased density of crop promotes desirable competition among plants- where main stem grows taller while the lateral branches are slowed down in their growth,

(2) In tobacco, artificial shading is used to produce large and thin leaves used for cigar wrapper, (3) In coffee plantations, the plants are grown under shade of trees (4) Tea plants and betel vine plants are also grown under shade of trees to improve quality of leaves.

When excess N is applied, in crops like rice mutual shading causes for lower photosynthetic ability. Besides, it also increases succulence causing increased incidence of diseases and pest attack ultimately reducing grain yield.

Many successful competitors create conditions of “stress” for other plants by growing rapidly/taller by producing large, dense canopies thus create a deep shade below. This makes it difficult for other crops to establish. For example: pulse crops after producing dense canopies become dominant over weeds.

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**Lecture-11**

# ALLELOPATHY

## 11.1 Definition

The term allelopathy was coined by Hans Molisch (1937), which is derived from Greek language (*allelon*: of each other; *pathos*: to suffer). It means “mutual harm or injurious effect of one upon the other”. Molisch defined the term allelopathy as “biochemical interactions detrimental as well as beneficial between all types of plants”.

In current use the term allelopathy refers to any effect; direct or indirect, stimulatory or inhibitory, mediated by a chemical compound released in to the environment by a given plant or microorganism (Rice,1984).The walnut tree (*Juglans nigra* and *Juglans regia*) is perhaps the best known allelopathic plant causing many crops and other plants in its vicinity to wither and die. The leaves, roots and fruits of this plant produce a hydroquinone, which is oxidized in the environment to juglone, this compound is responsible for the toxic effects on other plants.

## 11.2 CONCEPT OF ALLELOPATHY:

Allelo chemicals or allelopathins are released by the donor plants in to the environment through a variety of mechanisms *viz*., volatalisation from leaves, exudation from roots, and leaching from fallen leaves and Plant litter.

1. **Volatilization:** Volatile substances released from the radially spread leaves of parthenium inhibit growth of indigofera, bean, cowpea, tomato, ragi and wheat.
2. **Root exudation:** The hydrophobic exudates from the roots of sorghum inhibit germination in corn and root elongation in lettuce.
3. **Leaching:** A variety of chemicals may be leached from the aerial portions of plants by rainwater or by fog dip.

   Ex: Leachates from roots and inflorescences of *Cleodendron viscosum* inhibit growth of lettuce.

   The leachates of *Abutilon theophrasti* inhibit growth of soyabean.
4. **Decomposition of plant residues:** The plant residues of Rye (*Secale Cereale*) decrease the emergence of lettuce and prosomillet (*Panicum milliaceum*)

## 11.3 SOURCES OF ALLELOPATHIC CHEMICALS (ALLELOCHEMICALS PRESENT IN DIFFERENT PLANT PARTS):

Chemicals with allelopathic potential are present virtually in all plant tissues Including leaves, stems, roots, rhizomes, flowers, fruits and seeds.

**LEAVES** : *Parthenium, Celosia argentea, Amaranthus viridis*

**SHOOT** : *lantana camera*

**ROOT** : Wild oats, Sunflower, *Asparagus afficinalis*

**RHIZOME** : Quackgrass (*Agropyron repens*)

**FRUITS** : *Parthenium hysterophorous*

**SEEDS** : *Datura stromonium*

**WHOLE PLANT** : *Cyperus rotundus*

**11.3.1 Weed and Crop Species With allelopathic Potential:**

**a) WEED SPECIES:**

**Examples:** *Celosia aregenta, Parthenium hysterophorus, Lantana camera, Chenopodium album, Echinocloa crusgalli, Agropyran repens, Amaranthus retroflexus etc.,*

**b) CROP SPECIES:**

Numerous crops have been investigated more or less thoroughly for allelopathic activity towards weeds or other crops. A suppressive effect on weed, possibly mediated by the release of allelochemicals has been reported for a wide range of temperate and tropical crops. These include alfalfa (*Medicago sativa*), barley (*Hordeum vulgare*),clovers (*Trifolium* spp., *Melilotus* spp.) oats (*Avena sativa*) pearl millet(*Pennisetum glaucum*), rice (*Oryza sativa*) rye (*Secale cereale*), sorghums (*Sorghum spp*.), sunflower (*Helianthus annuus*), sweet potato (*Ipomoea batatas*) and wheat (*Triticum aestivum*)

**Example:** Certain cultivars of Wheat releases allelochemicals that can affect the root growth and seed germination of *Avena fatua* ( Wild oats).

**11.4 Natural products identified as allelopathic agents:**

Most of the allelochemicals are **secondary metabolites** that are produced as intermediate compounds in plant metabolism. They are derived from diverse chemical groups viz., organic acids, Aldehydes, terpenoids, steroids, phenolics, long chain fatty acids, Aromatic amino acids etc.,

1.***Parthenium hysterophorus*:** Parthenin, Caffeic acid, ,Ferulic acid, Chlorogenic acid,P-hydroxybenzoic acid, P-Coumaric acid, as inhibitor in Parthenium leachate.

2.***Sorghum halopens*** **:** Dhurrine (Cyanogenic glucoside), Chlorogenic acid, Coumaric acid and P-hydroxy benzaldehyde

3.***Lantana camera*** **:** Lentedene and Lancamarene in leaves and fruits

4 ***Argemone mexicana*** **:** Sanguinarine and dihydroxy sanguinarine

5. ***Euphorbia geniculata*** **:** Eupatol

6. ***Datura stromonium*** **:** Tropane alkaloids, Scopalamine and hyoscyamine in both seeds and foliage.

**11.5 MODE OF ACTION OF ALLELOCHEMICAL INHIBITORS**:

The following sites or processes are known targets for allelochemicals: cell division, production of plant hormones and their balance, membrane stability and permeability, germination of pollen, mineral uptake, movement of stomata, pigment synthesis, photosynthesis, respiration, amino acid syntheses, nitrogen fixation, specific enzyme activities and conduction tissue.

**11.6 FURTHER SCOPE FOR ALLELOPATHY:**

The viable weed management includes mechanical, chemical and biological methods of control. The mechanical weed control is time consuming, expensive and less effective, when the plant is well established. The selectivity, residual toxicity, prohibitive cost, non availability of herbicides, lack of technical know how and environmental pollution restricts the use of herbicides from wider adaptability, especially in cultivated lands. Thus economic and ecological limitations on control of many noxious weeds become more restrictive. Under these circumstances, the allelopathic means of controlling weeds offer a potential alternative.

Eg. Noxious and wide spread weed of *Parthenium hysterophorous* can be controlled successfully by introducing *Cassia uniflora* indicating potential allelopathic means of controlling this weed.

Understanding the concept of allelopathy helps us to develop natural herbicides. For example CINEMETHYLIN (this is natural compound having herbicidal properties. It is a derivative of 1, 4-cineole an allelochemical produced in Eucalyptus plant).

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**Lecture-12**

# PHYTOREMEDIATION

## 12.1 Definition:

Phytoremediation is an emerging technology that uses either naturally occurring or genetically engineered plants to remediate contaminated soils, sediments and water. The term ‘Phytoremediation’ consists of two words. A Greek prefix *phyto* (plant) and a Latin word *remedium* (to correct or remove an evil). Thus, “Phytoremediation is defined as a process in which various naturally occurring or genetically modified plants, including trees and grasses, are used to degrade, extract, detoxify, contain, and/or immobilize toxic pollutants from contaminated soil, water, and air…”

Organic solvents, detergents, pesticides, Heavy metals, crude oil and its derivatives are some of the common pollutants that affect soil, water and air. Most of the conventional methods (soil incineration, excavation and landfill, soil washing etc.,) used for cleaning up of these contaminants are either costly or cumbersome. It is estimated that, the conventional methods of remediation may cost from $10 to 1000 per cubic meter. Where as, phyto remediation (phyto extraction) costs are estimated to be as low as $ 0.05 per cubic meter. Therefore, phytoremediation is now accepted as a cost effective and an environmental friendly alternative to prevent pollution.

## 12.2 CONCEPT OF PHYTOREMEDIATION:

Various processes and mechanisms involved in phytoremediation are
1) Phytoextraction 2) Phytostabilisation 3) Rhizofiltration 4) Phytovolatalisation and 5) Phytotransformation.

### 12.2.1 Phytoextraction:

It is the best approach to remove the contaminants, particularly Heavy metals from soil. It is also referred as phyto accumulation. There are two basic strategies of phytoextraction

i) Chelate assisted phytoextraction or induced phytoextraction, in which artificial chelates are added to soil to increase the mobility and uptake of metal contaminant by plant.

For example: Use of synthetic chelators (EDTA, HEDTA etc.,) helps in rapid mobility and translocation of Pb and Cd from roots to shoots.

ii) Natural hyper accumulation, Here, the uptake of contaminants from soil by the plants is natural and un assisted. It is the natural ability of certain plant species to accumulate metals at a higher concentration. They are called as metallophyte plants or hyper accumulators. At least 45 families have been identified to have hyper accumulative plants; some of the families are Brassicaceae, Fabaceae, Euphorbiaceae, Asteraceae, Lamiaceae and Scrophulariaceae. The Brassicaceae family contains a large number of hyper accumulating species with widest range of metals.

These plants absorb contaminants through root system and store them in root biomass and/or transport them in to stems and leaves. Thus, at the time of disposal contaminants are typically concentrated in much smaller volume of the plant matter than in the initially contaminated soil or sediment. Through repeated planting and harvesting of hyper accumulators heavy metals concentration in the soil can be reduced to an acceptable limit.

A plant is called as a hyper accumulator if it accumulates the following heavy metals at the concentrations mentioned below.

| | |
|---|---|
| 100 mg $g^{-1}$ or 0.01% of its dry wt | Cd, As |
| 1000 mg $g^{-1}$ or 0.1% of its dry wt | Co, Cu, Cr, Ni and Pb |
| 10,000 mg $g^{-1}$ or 1% of its dry wt | Mn and Zn. |

Examples of different Hyper accumulator plants and their use in removal of contaminants. :

| S.NO | HYPER ACCUMULATOR PLANT | CONTAMINANT IT REMOVES | REMARKS |
|---|---|---|---|
| 1 | Thlaspi caerulescens<br>( Alpine pennycress) | Zinc, Cadmium | This is the best known hyper accumulator |
| 2 | a) Brassica juncea<br>(Indian mustard)<br><br>b) Ambrosia artemisifolia<br>(Rag weed) | Pb (Lead) | - |
| 3 | a) Azolla | Chromium | Hyper accumulating Aquatic plants |
| | b) Eichornia crassipes<br>(Water hyacinth) | Mercury<br>Cadmium<br>Chromium | |
| 6 | Helianthus annus<br>(Sun flower) | Uranium | This was observed after the Chernobyl nuclear accident |
| | | Arsenic | - |

### 12.2.2 PHYTOSTABILIZATION:

Unlike phyto extraction, the goal of phytostabilization is not to remove metal contaminants from a site, but rather to stabilize them and reduce the risk to human health and the environment. In this technique, plant roots immobilize a contaminant in soil through adsorption and accumulation or precipitation within their root zone.Thus, reduces the mobility of the contaminant and prevents its migration to the groundwater or air.

Ex: This technique immobilizes or precipitates heavy metals, so that they can not escape from mining areas.

### 12.2.3 RHIZOFILTRATION:

This is a phytoremediative technique designed for the removal of metals in aquatic environments. Rhizofiltration can partially treat industrial discharge, agricultural runoff, or acid mine drainage. Unlike phytostabilization, here the contaminants are not only adsorbed and precipitated, but also absorbed and concentrated in the root system (but not translocated to shoots).

Generally, terrestrial plants that can develop large root systems are raised in greenhouses hydroponically (with their roots in water rather than in soil). Once a large root system has been developed the plants are moved and floated in the contaminated water. Whenever the roots become saturated with contaminants the plants are harvested and disposed.

ex: removal of lead from water bodies using sunflower plants.

### 12.2.4 PHYTOVOLATILISATION:

Phytovolatilisation is the uptake and release of the contaminant in to the atmosphere by the plant ,either in its original or in a modified form.

Ex: Selenium is volatilized in to less toxic dimethyl selenide.
Mercuric ion is volatilised in to less toxic elemental mercury.

### 12.2.5 PHYTOTRANSFORMATION :

Phytotransformation is also called as Phytodegradation. In this process the contaminants are taken up by the plant roots and are degraded in side the plant body through the metabolic processes. Some times the breakdown of contaminants is also possible outside the plant, through the effect of compounds (such as enzymes) released by plants.

Ex:

- Hybrid poplar trees metabolize TNT (Tri Nitro Toluene), which is an explosive material. This is done by the enzyme nitroreductase produced by the plant.
- chlorinated compounds are dechlorinate by another plant produced enzyme dehalogenase

**12.3** APPLICATIONS OF PHYTOREMEDIATION IN AGRICULTURE AND INDUSTRY.

1) Agricultural lands situated near by industries, mining areas and oil refineries are facing the threat of pollutants. Fertility of these soils can be restored by using phyto remediation techniques.

2) It is a cheaper alternative compared to other types of physical and chemical remediation methods.

3) Rhizofiltration helps to reduce the load of contaminants reaching the water bodies. Thus, it helps to avoid the problem of eutrophication

4) In the process of phytoextraction, hyper accumulator plants are grown and harvested repeatedly, from the polluted site. This gives large amount of biomass. This biomass, how ever contains concentrated contaminants. Safe disposal of this material is possible only by incinerating the biomass. In this process of incineration lot of thermal energy is released which can be used for various industrial purposes.

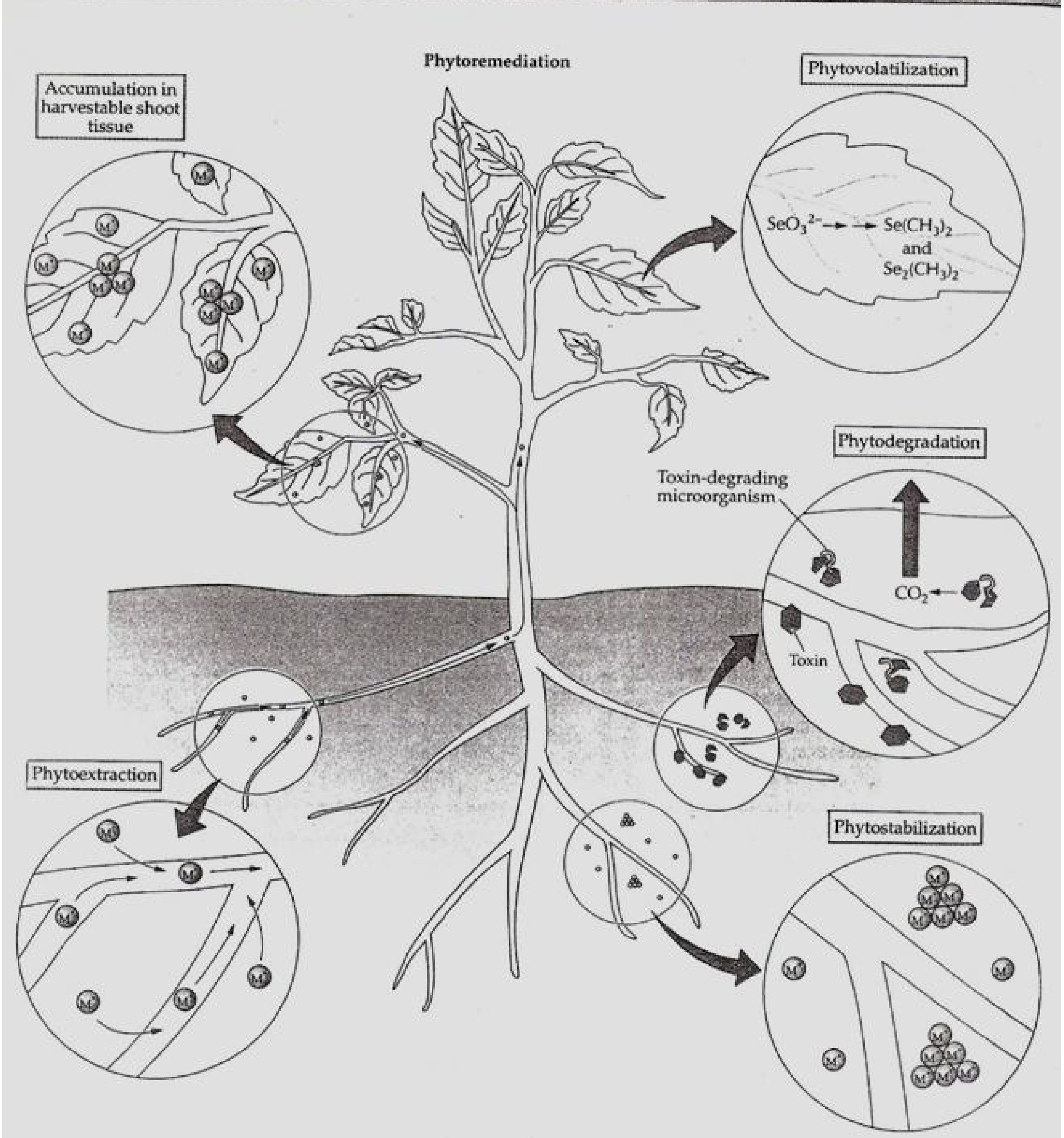
5) PHYTOMINING: This is a new area of technology, where in plants are used for recovery of valuable metals from the soil.

6) Phytoremediation is the least harmful method because it uses naturally occurring organisms and preserves the natural state of the environment.

**12.4** LIMITATIONS :

1. Phytoremediation is limited to the surface area and up to the depth occupied by the plant roots.
2. Slow growth and low biomass production by plants is a major set back
3. With this plant based technology it is not completely possible to stop the leaching of contaminants in to the ground water.
4. Possible bioaccumulation of o contaminants , if not monitored properly, can easily enter in to the food chain.

**Box 23.3** The conceptual basis for phytoremediation, the use of plants to clean contaminated soils, came from identifying plants that hyperaccumulate metals.

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**Lecture-13**

# POLLUTION

## 13.1 POLLUTION AND POLLUTANTS

Pollution is any unfavorable alteration of our surroundings wholly or largely as by-products of man's action through direct or indirect effects on changes in energy patterns, radiation levels, physical and chemical constituents and abundance of organisms.

A pollutant can be any chemical or geochemical substance, biological organisms or products that are released intentionally or inadvertently by man into environment with potential adverse effects.

Human beings by many of their activities *viz.,*industry, automobile traffic, agricultural and domestic use of chemicals, and above all the extravagant consumption of fossil fuels, release phytotoxic substances into the environment. They are taken up by the plants from air, water, or soil.

Pollution may be studied in terms of media (e.g. Air, water and soil that are polluted or in terms of pollutants that pollute the media like $SO_2$,$CO_2$,CO,Fluorides,Nitrates,radioactive substances etc.)

## 13.2 AIR POLLUTION- SOURCES AND PHYSIOLOGICAL EFFECTS ON PLANTS.

Air pollution means the presence of one or more air contaminants in the outdoor atmosphere such as dust, fumes, gas, mist, odor, smoke, or vapor in quantities or characteristics, and of duration, such as to be injurious to human, plant or animal life. Some of the important air pollutants and their effects on plant growth and development are listed below.

### 13.2.1 Sulphur dioxide ($SO_2$)

It is a primary product of the combustions of sulphur containing fossil fuels. Coal burning presently accounts for 60 per cent of the sulphur dixoxide pollution. Sulphur oxides are absorbed by water and go into solution in water. If not absorbed, it soon oxidized to the less toxic $SO_3$ and finally to sulfuric acid mist. Sulphuric acid mists on Condensation nuclei and fall upon the vegetative canopy and affect the plant growth.

### 13.2.2 Oxides of nitrogen (NO)

These are the byproducts of combustion of atmospheric nitrogen and oxygen. The initial product of this reaction, nitric oxide (NO) is oxidized to Nitrogen dioxide ($NO_2$), utilizing the oxygen in the atmosphere. Energy from sunlight quickly splits the $NO_2$ back to NO and atomic oxygen which combines with the molecular oxygen of the atmosphere to form ozone ($O_3$). Thus, Ozone ($O_3$) accumulates in the atmosphere. When the leaves are exposed to $O_3$, the guard cells of the epidermis quickly lose turgor and the stomatal aperture closes. Ozone may destroy structural integrity of membranes. It damages tobacco, tomato, bean, pine etc. NO in the urban atmosphere reacts with several hydrocarbons (Ex. Aledehydes) and thus helps in production of secondary pollutants like PAN(Peroxy Acyl Nitrates).

### 13.2.3 Carbon dioxide ($CO_2$)

Combustion of fossil fuels and automobile exhausts increase the $CO_2$ in the atmosphere. Continued increase in $CO_2$ (0.5 % per annum)has a warming effect that melts the polar ice and bring changes in the ecology of seas. Large scale floods are some of the potential consequences. On the other hand, increased $CO_2$ content could increase the rate of photosynthesis.

### 13.2.4 Carbon monoxide (CO)

It also comes mostly from exhaust fumes of motor vehicles and industrial works. At high concentrations, plants produce toxic symptoms like leaf curling, ageing and reduction in leaf size. The CO competitively inhibits nitrogen fixation by legumes.

### 13.2.5 Smog to PAN

A musty, acrid, irritating pall of smoke which clung relentlessly and turn to dirty brown haze is called as Smog. Its content cause reduced visibility. They show symptoms like glazing, silvering and bronzing on petunia, lettuce, spinach and sugar beet crops. Necrosis of lower leaf surface, appears on sensitive species (bean, spinach) causing serious crop losses. The contents of Smog are named as peroxi acyl nitrates (PAN) and ozone. Plant damage caused by Smog is attributed to the PAN compounds detected in Smog.

### 13.2.6 Fluorides

Both gaseous and particulate fluorides are released into the atmosphere for the aluminum factories, manufacturing units of fluoride compounds, glass, pottery and brick works. Fluoride enters the plant through stomata. In intercellular spaces they dissolve in water and transported to the leaf tips and margins where it accumulates. Chloroplasts are presumed to be the major site of accumulation of fluorides. Accumulation of toxic concentrations of fluorides in broad-leaved species causes necrosis, chlorosis or both at leaf tip and margin.

### 13.2.7 Ethylene ($H_2C=CH_2$)

Ethylene is released from illuminating gas, burning coals, wood and automobiles. Excessive ethylene at too early stages of leaves accelerates respiration, causing premature senescence and abscission. Cotton within a mile distance to ethylene source exhibits leaf abscission, scattered seedling death, vine-like growth habit, malformed vegetative and reproductive organs.

### 13.2.8 Ammonia

As pollutant ammonia escapes from refrigerator pre-cooling systems of cold storage rooms and anhydrous ammonia used in fertilizer industry. The phytotoxic effects of ammonia include dark spots or complete blackening of leaves, bleached white (barley) and rusty along the leaf margins (wheat and rye).

### 13.2.9 Chlorine

Chlorine escapes into the atmosphere from industrial accidents, manufacturing processes and leaking chlorine cylinders. Chlorine is required for photosynthetic $O_2$ evolution. The sensitive species are radish, alfalfa, tobacco, beans, citrus, potatoes etc. whilst, barley, sugar beet, maize, tomato are tolerant. The symptoms of chlorine injury are of three basic types: Chlorosis, necrosis and reddening.

### 13.2.10 Methyl-Isocyanate (MIC)

Methyl Iso cynate gas is deadly poisonous to human beings, animals and plants as well. It emanates from pesticide preparations and its accidental leakage. The Bhopal gas tragedy which occurred in 1984 caused complete defoliation in a variety of trees. The fruits of guava developed cracks but surprisingly mango, palms and banana were not at all affected.

## 13.3 CONTROL OF AIR POLLUTION

1. Use of settling chambers, bag filters, electrostatic precipitators, gas absorbers, catalytic combustion agents.
2. Chimneys should be raised so that smoke and particulate matters are thrown high and are carried by wind for dispersal.
3. Recycling of harmful chemicals and their reuse.
4. Use of high temperature incinerators for reduction in particulate ash production.
5. Generally industrial activities should be located away from residential localities.

6. Environment engineers should have say before setting up industries in particular place. Because the nature of pollution, local conditions and meteorology may not be suitable for particular industry in particular area.
7. Use of unleaded petroleum in vehicles.
8. Desulphurization of fuel or removal of sulphur gas after combustion.
9. Control over use of fossil fuels.
10. Exhaust emission by automobiles must be reduced by mechanical means.
11. Electrification of railway tracks.
12. Use of non-combustive sources of energy, e.g. solar power, unclear power, geothermal power, tidal power etc.
13. Use of cooking gas (L.P.G) in place of wood and dung cakes.
14. Afforestation of mining area on priority basis.
15. Plants which can reduce pollutants should be cultivated more and more(phytoremediation).

## 13.4 WATER POLLUTION- SOURCES AND PHYSIOLOGICAL EFFECTS ON PLANTS

Water becomes polluted when its quality or composition is changed by man's activities. Thus it becomes less suitable for drinking, domestic, agricultural, recreational and for fisheries or other purposes for which it would otherwise be suitable in its natural state. Pollution of water by effluents is, mainly due to poisons, deoxygenation and suspended matter. The following are some of the important sources of water pollution.

### 13.4.1 Domestic wastes and effluents

Water pollution occurs when the quantity of sewage effluent is too large to be broken down through biological degradation.

### 13.4.2 Industrial wastes and effluents

Main industrial source of pollution are pulp and paper mills, sugar mills, iron and steel factories, and petroleum refineries. Some of the contaminants released by these industries are, lead, detergents, cyanide, chlorine, phenol benzyl derivatives, ammonia, nitrates and soluble carbohydrates. They cause deoxygenation and anaerobic conditions.

### 13.4.3 Agricultural Chemicals from agricultural Lands.

**a) Fertilizers**

Nitrogenous, phosphatic and other fertilizers leached and washed into water bodies, cause excessive growth of algae, foul smell rendering water unfit for drinking (EUTROPHICATION). The polluted water with excessive nitrogen gives bad effects on rice quality. It promotes vegetative growth and reduces the quality of grains. at moderately high nitrogen content, reduction and decomposition of organic substances produce bivalent iron and hydrogen sulphide. Excess of these together with organic acids hampers the nutrient metabolism of rice and suppresses plant growth.

**b) Pesticides**

Some of the insecticides, DDT, dialdrin, BHC when washed into water bodies affect growth and survival of fish. Arsenical compounds turn out into more toxic arsenate. Though increased use of pesticides enhances production, their contribution to the total environmental pollution over their benefit is insignificant.

**c) Other pollutants**

These include empty cans, bottles, automobile junk, waste pieces of rocks, steel, iron etc. these heaped at a place harbor animals like rats, cockroaches, flies etc.

### 13.4.4 Heavy metals

Pollution by very small amounts of lead, cadmium and arsenic compounds may occur when water flows through rivers and polluted soil.

**a. Lead (Pb)**

Lead smelting, gasoline, pesticides, paints, lead lined utensils are the lead poisoning sources. It is a cumulative cellular poison. Lead taken up by plants is accumulated in the cell wall.

**b. Cadmium (cd)**

Cadmium is added to soil through phosphate fertilizers, sewage water, metal smelters and zinc smelters. Many plant species retain Cd. It is toxic to plants and disturbs enzyme activity. In plants excess Cd disturb Fe metabolism and cause chlorosis. Cadmium hampers the growth of rice, soybean, egg plant than tomato and cucumber.

**c. Arsenic compounds (As)**

The sources are arsenical pesticides and detergents. Under heavy water pollution the arsenate is broken down to the more toxic arsenate. Many plants concentrate arsenic compounds in their tissues.

**4. Atomic wastes**

Radioactive pollution arises from the disposal of atomic waste and radioactive gasses released from nuclear installation and from the fall out produced by testing nuclear weapons. The accumulation of radio nuclides in the tissues may lead to cancer in the human body. Very high-energy radiations produce ionizing radiations and are the chief cause of injury to protoplasm. Rapidly dividing cells are more sensitive. In higher plants sensitivity to ionizing radiation has been shown to be directly proportional to the size of the cell nucleus.

There is no fool-proof method of disposal of radioactive wastes. In many cases, the radioactive wastes are sealed in steel drums or concrete blocks and sunk into the sea to await their natural decay.

## 13.5 MANAGEMENT OF WATER POLLUTION

Biodegradable pollutants alone are not responsible for water pollution, though they indicate level of pollution through BOD values. Besides this, a substantial pollution load is contributed by non-degradable or slowly degrading pollutants, such as heavy metals, mineral oils, pesticides, plastic material etc. that are dumped in to water. For Biodegradable pollutants, pollution may be controlled at source by their treatment for reuse and recycling (e.g., waste water treatment plants). The non-degradable toxic substances can be removed from water by suitable methods

For ex. Reverse osmosis is commonly used to desalinate the brackish water and can also be used for purifying water from sewage.

Council of Scientific and Industrial research, New Delhi could device ION EXCHANGE technique to remove ammonia from water.

In addition to these methods, some standards, conditions and requirements are to be legally enforced by the Government through Acts ( Eg. Environment (protection) Act,1986, Prevention and control of water pollution Act,1974)

## 13.6 SOIL POLLUTION

Soil is the basis of agriculture. All crops for human food and animal feed depends on it. Soil is the ultimate recipient of enormous quantity of man made waste products. Industrial wastes, sewage, sludge and polluted water cause soil pollution.

### 13.6.1 Source of soil pollution

The sources which may pollute the soil are two fold.

a) Agricultural sources: Animal wastes, pesticides, fertilizers etc.

b) Non-Agricultural sources: Wastes related to modern life activity of human beings.

### 13.6.2 EFFECT OF SOIL POLLUTANTS ON PLANTS

Materials that find their entry into the soil system having long persistence and accumulate in toxic concentrations are called as soil pollutants. There are four types of soil pollutants.

#### a. Inorganic toxic compounds

Inorganic residues in industrial waste present serious problem of disposal. They contain heavy metals which have potential toxicity. Among heavy metals nickel, cadmium and lead are have high toxic potential, zinc and mercury moderate and chromium low potential. Arsenic compounds which are used in insecticidal preparations are also having high toxic potential.

#### b. Organic wastes

Organic wastes of various types cause pollution hazards. Domestic garbage, municipal sewage and industrial wastes when left in heaps or improperly disposed seriously affect the health of human beings, plants and animals. Sewage contains detergents, water softeners, borates, phosphates and other salts in large amounts.

#### c. Organic pesticides:

Pesticide persistence in soil and movement into water streams may also lead to their entry into food and create health problems (**Biomagnification**). Pesticides particularly aromatic organic compounds are not degraded rapidly and therefore have long persistence time.

**Persistence time of some selected pesticides**

| Pesticide | Persistence time |
|---|---|
| Chlordane | 12 years |
| BHC | 11 years |
| DDT | 10 years |
| Aldrin | 9 years |
| 2, 3, 6, TBA (Trichlorobenzene) | 2-5 years |
| Diuron | 16 months |
| Simazine | 17 months |
| 2, 4 -D | 2-8 weeks |

The main method of checking pesticides pollution is to increase the organic matter content of the soil and choose such pesticides which are non-persistent and leave no harmful residue.

**d. Radioactive wastes:** Wastes from atomic reactors and nuclear power plants containing different kinds of radioactive isotopes which are most dangerous. These wastes affect aquatic plants and animals also. They cause ionization of various body fluids, gene mutations and chromosomal mutations.

### 13.6.3 MANAGEMENT OF SOIL POLLUTION

- Sanitary land fills are to be promoted in place of open dumping.
- Recycling and reuse of materials like Paper, Metals and Glass is to be encouraged.
- Organic waste, if treated properly, becomes a good quality compost.

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**Lecture-14**

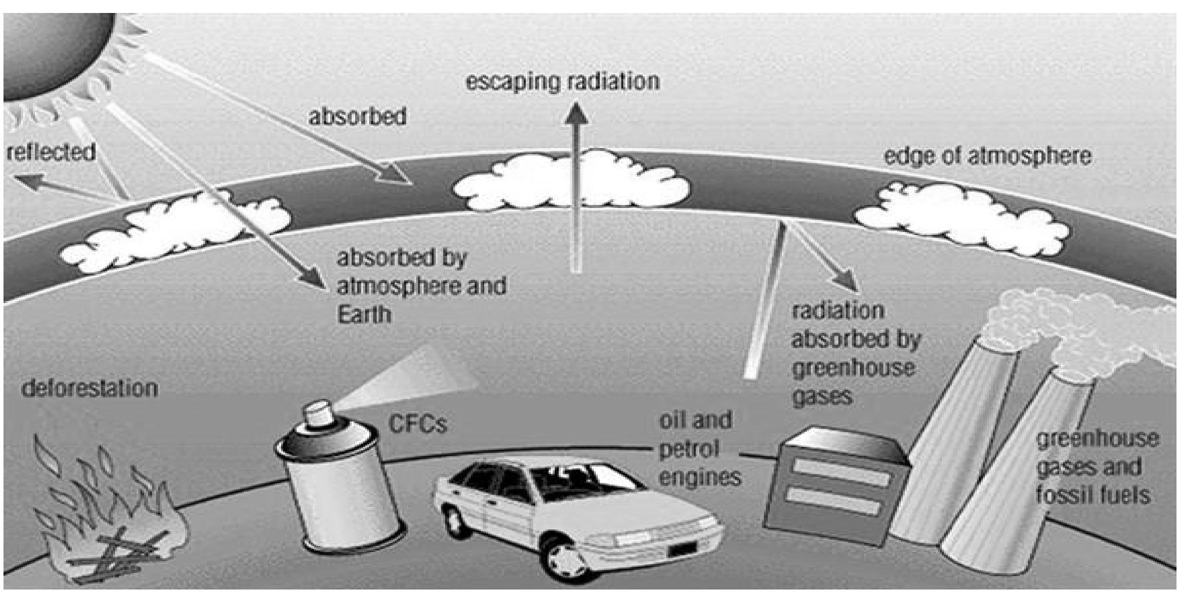
# GLOBAL WARMING

## 14.1 GREEN HOUSE EFFECT

The atmosphere is able to keep the earth habitable because some of its constituent gases can absorb heat radiated from the earth's surface preventing it from escaping into space. These gases are called as greenhouse gases (GHGs). They act as a glass pan of a green house which allow solar radiations to pass through and heat the surface of the earth but does not allow the heat radiated from the ground to pass through, thereby trapping it in the process. This heat trapping phenomenon is known as greenhouse effect. It is a natural phenomenon without which earth would be to too cold to support life.

Some of the sun's rays that penetrate the layer of $CO_2$ strike the earth and are converted into heat. The heated earth reradiates this absorbed energy as radiations of longer wavelengths, much of this does not pass through $CO_2$ and water vapor in the atmosphere and adds to the heating of the earth's atmosphere. There are several greenhouse gases, the major and important ones are carbon dioxide ($CO_2$), methane ($CH_4$), chlorofluorocarbons (CFCs), nitrous oxide (NOx) and ozone ($O_3$) as shown in the table 1.

$CO_2$ and $CH_4$ are produced by natural as well as man-made sources while others such as CFCs are purely man-made.




**(SCHEMATIC REPRESENTATION OF GREEN HOUSE EFFECT)**

The greenhouse effect phenomenon, indeed, is a reality. Form mid-1700 to 2000, all the major greenhouse gases have increased at a rapid rate, CFCs by 5%, methane by about 1%, $CO_2$ by 0.5% and $N_2O$ by 0.3 -0.4 % a year(table.2) List of countries ranked by total greenhouse-gas emissions in 2005 by WRI is shown in table.3. Due to the heat trapping characteristic of GHGs, the temperature of the planet earth has been kept at an average temperature of about $15^0$ C which otherwise could have been at temperature of about $-18^0$C without $CO_2$ envelop and other greenhouse gases (i.e., the greenhouse effect for the earth is $33^0$ C).

Earth's greenhouse effect turns out to be consistent with temperature on the two neighboring planets, Mars and Venus. Mars has very thin atmosphere and virtually no $CO_2$ and maintains an average temperature of -53$^0$C, while Venus which is about 70,000 times larger than that of the earth, with its $CO_2$ dominated atmosphere, suffers from -46$^0$ to +477$^0$C (i.e., greenhouse effect for Venus planet is 523$^0$C).

Table.1 Major Greenhouse Gases as studied by WRI

| Name | Composition | Sources of emission | Contribution (%) |
|---|---|---|---|
| Carbon dioxide | $CO_2$ | 1. Fossil fuel combustion (coal, oil, natural gas)<br>2. Deforestation and land use changes. | 61 |
| | | | |
| Methane | $CH_4$ | 1. Enteric fermentations in cattle and insects<br>2. Biomass burning and Garbage land fills<br>3. Coal mines and natural gas leaks<br>4. Rice puddle fields<br>5. Swamps and tundra | 15 |
| Chlorofloro carbons (CFCs) | CFC11<br>CFC12<br>CFC113<br>CFC114<br>CFC115 etc | 1.Aerosols (spray propellants)<br>2. Refrigeration and air-Conditioning<br>3. Plastic foams<br>4. Industrial solvents<br>5. Sterilants for medical supplies | 11 |
| Nitrous oxide | $N_2O$ | 1. Fertilizer use<br>2. Fossil fuel combustion<br>3. Biomass burning<br>4. Changing land use | 4 |
| Ozone and others | $O_3$, $CO_2CO$, NO, $NO_2$, $SO_2$ $C_2H_4$ | 1.Chloro fluoro carbons at stratosphere (released by jet planes) | 9 |

In the past, before the industrial revolution, most $CO_2$ and $CH_4$ came from natural sources and CFCs were not known. Natural processes kept the levels of these gases within the limits. As a result, through most of human history, the earth's atmosphere blanket was held at the average global temperature at around $15^0$ C. but over the last 100 years the levels of the entire major greenhouse gases have been raising steadily, principally as a result of human activity such as industrialization, deforestation and agriculture.

Table.2 The trend of GHGs increase from mid-1800 to 2000 A.D.

| S.NO | Green House Gas | Annual increase |
|---|---|---|
| 1 | CFC'S | 5 |
| 2 | Methane | 1 |
| 3 | $CO_2$ | 0.5 |
| 4 | $N_2O$ | 0.3-0.4 |

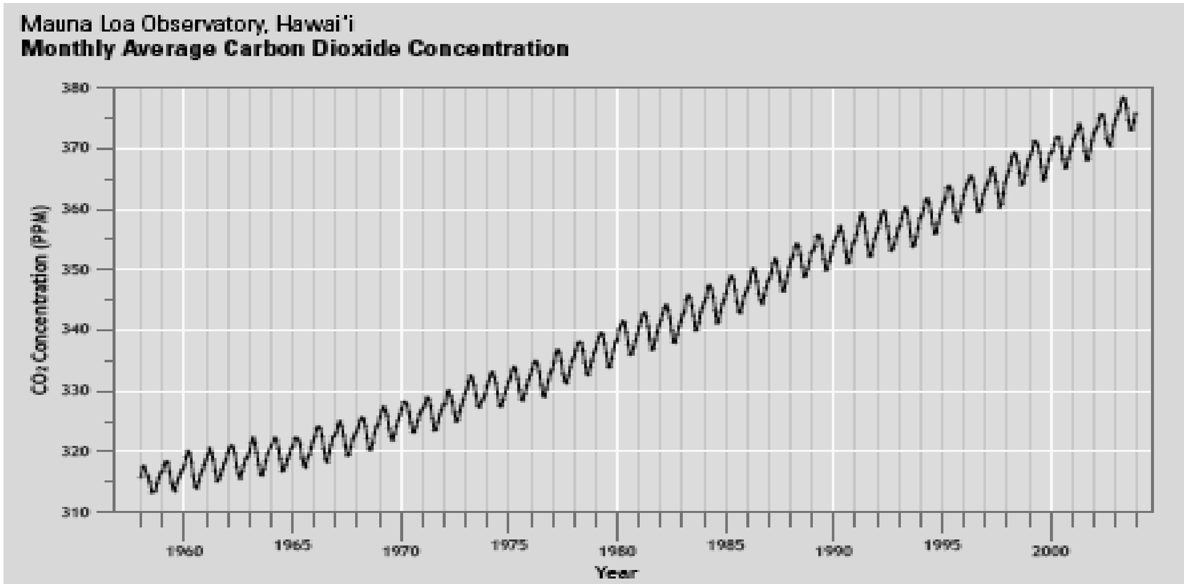
Table3 List of countries ranked by total greenhouse-gas emissions in 2005. (It is based on data for carbon dioxide, methane, nitrous oxide, perfluorocarbon, hydrofluorocarbon, and sulfur hexafluoride emissions compiled by the World Resources Institute.)

| **Rank** | **Country** | **Percentage of global total** |
|---|---|---|
| 1 | China | 16.36% |
| 2 | United States of America | 15.74% |
| 3 | European Union (27) | 12.08% |
| 4 | Brazil | 6.47% |
| 5 | Indonesia | 4.63% |
| 6 | Russian Federation | 4.58% |
| 7 | India | 4.25% |
| 8 | Japan | 3.17% |
| 9 | Germany | 2.27% |
| 10 | Canada | 1.83% |

## 14.2 CAUSES OF GLOBAL WARMING

### 14.2.1 $CO_2$:

The single largest contributor to the global greenhouse effect is **$CO_2$** which is produced wherever fossil fuels are burnt. It has been estimated that by mid-1700 the average $CO_2$ level in the earth's atmosphere was 280 ppm that stood 315 ppm by 1988 (which is about 375ppm as of now) and by the middle of 2050 if the current rate of fossil fuel burning continues, it is likely to reach 600 ppm. The present growth rate of $CO_2$ is 0.5%.




The Mauna Loa observatory at Hawaii Island constitute the longest continuous record of atmospheric CO2 concentrations available in the world. This record is considered to be a precise record and a reliable indicator of the regional trend in the concentrations of atmospheric CO2 in the middle layers of the troposphere.

### 14.2.2 METHANE:

Another important greenhouse gas which could affect the climate of the earth is **methane ($CH_4$),** the level of which is rising alarmingly. It is significant to note that the gas is only about 5% of that $CO_2$, but it is 20-30 times more effective than that of $CO_2$ in producing greenhouse effect. Most methane is produced by natural biological processes such as bacterial action in the gut of cattle and other ruminants, in Paddy puddle fields, marshy lands, garbage dumps and landfills. To some extent it is also produced by mining of coal and oil distribution of natural gas. Leakage of natural gas from pipelines or geological fissures also contributes to the atmospheric methane level. In mid-1700 the concentration of methane averaged 800 ppm and stood at 1700 ppm 1988. It is rising at the rate of 1-2% a year.

### 14.2.3 Chlorofluorocarbons:

The third major greenhouse gas is a group of synthetics, called **chlorofluorocarbons (CFCs)** and these versatile chemical were manufactured only in 1960s. They are used extensively as refrigerants, plastic foaming agents, aerosol propellants and cleaning agents. CFCs first attracted the attention of scientists in 1970s when it was discovered that they could have destructive effects on the stratospheric ozone layer. As a greenhouse gas, it is twenty thousand times as powerful as $CO_2$. Moreover, they are extremely persistent and can remain in the stratosphere for decades.

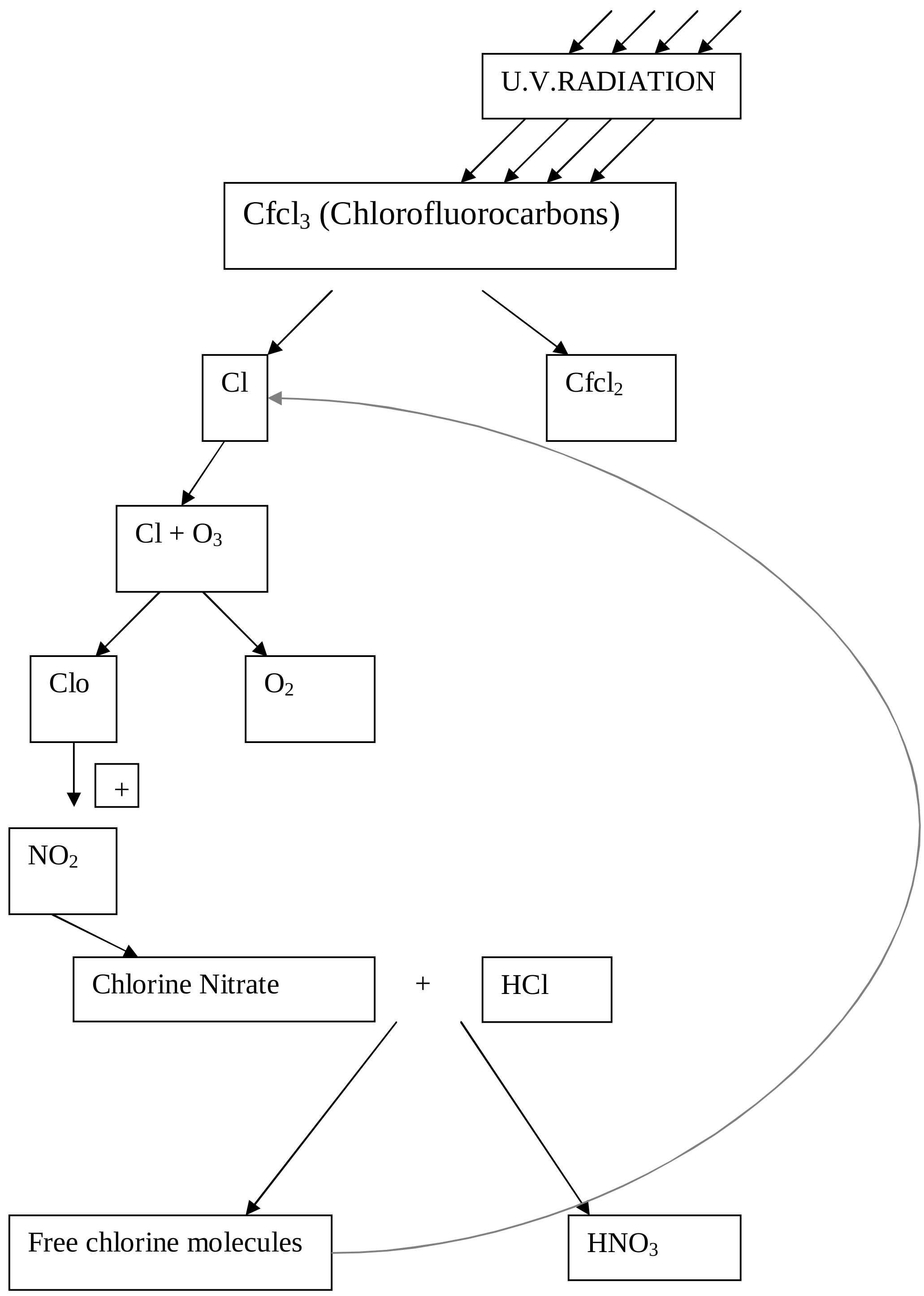
Although CFCs stand after $CO_2$ In their contribution to global warming but their atmospheric concentrations are extremely small. The current level of CFCs is about

700 ppm and is rising at 5% a year. CFCs once released in to atmosphere, persists for hundred years. Americans are successful in recapturing the CFCs present in the atmosphere.

**CFCs contribute global warming through two different routes:**

1. As greenhouse gas like $CO_2$ , can trap heat resulting in rise in global temperature
2. Directly responsible for destructing the OZONE layer, consequently responsible for increased temperature in the troposphere.

**14.2.3.1** A simple version of stratospheric $O_3$ depletion by the breakdown of CFCs is shown in the following figure.



### 14.2.4 Nitrous oxide

Nitrous oxide is yet another greenhouse gas. It is produced by burning of coal, oil and biomass along with $CO_2$. it is also released from nitrogen based fertilizers applied in agricultural soils. During the pre-industrial period, the atmospheric level of nitrous oxide was 280 ppm which stood to 310 ppm in 1988. the present level is around 330 ppm and rising at 0.3 % to 0.4 % every year.

## 14.3 IMPACT OF GLOBAL WARMING ON CLIMATE AND AGRICULTURAL PRODUCTIVITY

The Stockholm Environment Institute has reported that natural ecosystems can adapt to a temperature rise at the most $0.1^0$C per decade. However, IPCC (International panel for climate change) (1990) has predicted that the increase in global average temperature of about $1^0$C above the present value by 2025. Many scientists believe that temperature would rise more than $2^0$ C within next 50 years. Such a rise in global temperature would have the following adverse environmental consequences:

### 14.3.1 Biomass and Ecosystem:

Many species particularly plants would be unable to migrate to new and suitable habitats., leading to rapid loss of biological diversity and a resultant loss of natural resources of great economic potential. Vegetation influences hydrological cycle and the relationship between climate, vegetation and hydrological cycle continue to be fragile. India could have more rainfall during monsoon to cause devastating floods and severe erosion. Wheat crop in particular would be the victim of increase in temperature and precipitation pattern.

### 14.3.2 Monsoon pattern & Sea level rise:

The increase in temperature will cause more frequent storms in many parts of the world, including the regions which never experienced any storms earlier. Oceans will warm and expand, causing sea levels to rise and flood many of the world's highly productive deltaic areas, including vast tracts of Bangladesh, Egypt, Indonesia, china and India. Island nations such as Netherlands, Maldives face the threat of inundation and wipeout all biological life including human habitats. Melting of glaciers and icecaps, as a consequence of global warming would also contribute to rise in sea level.

**14.3.3 Agriculture and Food production:** Climate change would pose serious problem for agriculture especially rain fed farming such as

(1) change in the length of growing season affecting mean yield,

(2) change in the incidence of pests and diseases and weeds and

(3) loss of useful resources.

Global warming could severely disrupt marine ecosystems as well as agriculture. The flooding of many coastal wetlands as the oceans as the oceans rise would mean the loss of nurseries for many fish, shrimp and birds.

**14.3.4 Groundwater:** Groundwater supplies in several parts of the world could become contaminated with sea water as the sea water move into near coastal lands creating even drinking water problem in addition to the problem of quality irrigation water.

## 14.4 Measures to reduce the buildup of GHGs

The suggested measures are as follows:

1. Improving the efficiency of energy production and use
2. Consumption of less carbonaceous fuels, switching up from carbon – intensive fuels such as coal to hydrogen – rich fuels, such as natural gas
3. Rapid development of carbon free energy sources, such as solar, wind, tidal, geothermal and nuclear energy.
4. Total ban on production and use of CFCs
5. Halting deforestation and encouraging massive afforestation and reforestation.
6. Developing consensus among many countries that “atmosphere” is a common heritage of human kind and need to be protected.

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**Lecture-15**

# CONTROLLED ENVIRONMENT

## 15.1 INTRODUCTION

In agriculture there is continuous demand for improved varieties / plant types that increase both crop production and quality of farm produce. Plant growth and development are dependent in the first instance on genetic potential and then on the interaction with the environment as well as growing conditions. The variations between plants caused due to differences in environmental variations such as light (radiation), temperature, moisture etc. are not inherited. The variations originating due to the genetic makeup are only heritable.

To study the effect of genetic factors, the varying effects of environment must exclude. Similarly, to know the exact influence of a single environmental factor any variation caused by genetic effects must be excluded by using pure (homozygous) lines or by using vegetatively propagated clones.

Of late commercial cultivation of high value crops under controlled environmental conditions is gaining popularity. In this context controlled environments are very much useful in meeting the above requirements.

## HISTORICAL PERSPECTIVE

Controlled environment is not a new concept. High quality vegetables and other crops have been produced in controlled environment, such green houses for centuries.

As early as 14-37 A.D.: Romans used talc window covering to extend plant growth.

By the end of 15$^{th}$ century; Green / glasshouses were made use intensively N. Europe, in Dutch.

Middle of 1800 s : hot beds used in producing the seedling .

Late 1800s : Structures for growing several crops appears regularly.

1921- F.G Gregory first person to make a study the growth of plants for longer period of time in a glasshouse.

1943- F.W.Went – Showed the possibility of growing plants by providing a wide range of different controlled environment with in a single installation.

## 15.2 PURPOSES OF CONTROLLED ENVIRONMENT

Controlled environment incorporates the manipulation of air and root – zone temperatures, relative humidity and radiant energy (light), air / wind velocity, concentration of $CO_2$, root zone $O_2$ concentration, nutrients and moisture supply to control plant / crop growth as per requirement in research and also in areas where natural environment limits / prohibits normal plant growth.

The following are various purposes for which controlled environments are used are:

### 15.2.1 Production of uniform plant material

In research to conduct experiments availability of uniform plant (homozygous) material with little of no variation among themselves is a pre-requisite to test any hypothesis. Use of uniform plant material greatly facilitates research by reducing the number of replications required enabling the layout simplified. With controlled environments now available, it is possible to produce plant / crop material with great degree of uniformity.

Commercially, banana cultivation is now making the use of plantlets produced in controlled environment / tissue culture

### 15.2.2 Reproduction of seasonal conditions

Many a times it may not be possible to study a particular aspect of plant growth, for example cold tolerance in crops such as rice, which occurs at a certain season, thus restricting the experimentation to off season in a year. By using suitable controlled environments for example, growth cabinets, it is possible reproduce the particular seasonal conditions and carryout experiments, at any time during the year irrespective of weather, thus accelerating experimentation programme.

### 15.2.3 Altering growth and development

**a) <u>Hastening growth rate</u>:**

Where rapid growth is needed in experimental work, it is possible to provide conditions that induce and sustain high growth rates, once the requirements of plant are known. In United State commercially lettuce seedlings take about 24 days in summer and over 48 days in winter. Farmer produce lettuce seedling in winter using controlled environments with supplemental lighting where the grow–out time is reduced to 30 days for marketable produce.

**b) <u>Acceleration of development</u>:**

When there is a requirement of plants producing viable seeds to study the plants through successive generations, plants are brought to flowering pre-maturely to set seed in controlled environment by altering growth conditions in such a way that there is rapid phonological phage occurring terminating in seed.

**c) <u>Retarding natural development:</u>**

Just similar to hastening up maturation, it is possible to use keep plants in vegetative condition by using controlled environment and prevent them from maturing.

### 15.2.4 Studying the environmental factors on plant growth

The most important use of controlled environments world – wide is the study of environment effects / variations in relation to growth and development of plants / crops as well as animals / organisms. Normally, weather is infinitely variable, unpredictable and complex. It is most difficult to determine precise effect of any one factor on growth and development of an organism / plant. Through controlled environments it is possible to study the influence environmental factors at various levels and duration plants.

With the availability of controlled environments, now it is possible to study the alarming "Global warming- Green house effect" and even predict the future through computer simulation. For example scientists at International Rice Research Institute (IRRI), Philippines and several others assessed how may be affected by UV- B radiation, increases in $CO_2$ and potential increase in global temperature. They also analyzed and studied precisely the possible contribution of rice cultivation to climate change through emission of methane ($CH_4$) and other greenhouse gasses.

Controlled environments are also finding application in space research with National Aeronautic and Space Administration (NASA). Scientists are developing a working model of specially designed space growth chamber that can be used in orbiting space stations to produce fresh vegetables for astronauts on long duration missions.

### 15.2.5 Testing variety response to weather

In any crop improvement programme, varieties need to be developed suited to particular area of with a wider adaptability. It would take many years to decide whether a variety can grow and yield better is a particular area. With controlled environments made available, it is possible now, to ascertain the response of new varieties by comparing their reactions with those of established local varieties in any are of known meteorological characteristics.

### 15.3 DESIGN OF STRUCTURES

Controlled environments encompass various systems and practices of controlled plant growth ranging from hot beds and plastic row tunnels to hydroponics; growth rooms to completely enclosed artificial lighted conditions. The complexity and cost of equipment depends upon accuracy, precision and space needed. From stand point of commercial production, these require significant investments in capital, labor and growth skills for crops of high economic value, necessitating yield substantially superior in quality and quantity. In Japan, where available land is scarce, controlled environments have become essential segment of agriculture industry.

The salient features of various types of structures are as follows

#### 15.3.1 Greenhouse / Glasshouse:

In general, greenhouse / glasshouse are large structures designed to provide protection from variable weather conditions such as excessive heat or cold, winds, hails and snow and create an internal environment conducive for plant growth. The entire roof and often part of wall in the structure are glaze (glazing – a derivation from additional use of glass as a covering material) and exposed to normal light. There are three types of covering typically used in greenhouse: glass, plastic or polyethylene films, rigid plastic panels. In early times, glass was used in greenhouses (hence, the name glasshouse) a covering. At present, 80% new greenhouses in U.S.A., Netherlands and Germany are covered with plastic polycarbonate panels have greater tolerance to hail storms than acrylic used in greenhouses it farms

#### 15.3.2 Growth Cabinets:

These are relatively small structures and inexpensive with sleek design and have controlled mechanisms of all environmental variables such as light, temperature, relative humidity etc. enable growing of plants / organisms as desired with high degree of precision. These are not walk- in chamber where the operator gains access from only outside

#### 15.3.3 Temperature Controlled Rooms:

These rooms are large enough to admit operator / trolleys, with fine control of temperature often relative humidity, but with relatively low light intensity. These are unsuitable for long – term grow of higher plants and hence referred to as "temperature controlled rooms" rather than growth rooms. They are largely used by scientists concerned with research on animals and / or insects. These are used scientists in plant science research as dark rooms to house plants at night. They provide constant temperature control or even cyclic temperatures.

**15.3.4 Growth rooms :**

These are also large rooms with ample pathways for the operator (s) to move around with provision to regulate temperature precisely within $\pm$ $2^0$ C by standard heating / cooling systems. Temperature ranges from – 5 to $+45^0$ C with a constant 60 – 80% relative humidity. These rooms are not exposed to din sunlight but equipped with a provision for sufficient artificial light. In some structures, the light are include within the experimental volume (internal lighting) while in others lights are housed above a transparent screen and thus are separated from experimental area (external lighting). Compared to growth cabinet these structures are greater in cost. These structures find extensive use in tissue culture / biotechnology laboratories.

**15.3.5 Phytotrons :**

Phytotrons are complex installations which include a large number of individually controlled growth rooms consisting glass / greenhouses, where plants can be moved easily from one controlled environment another. Just as in the case of others all the environmental factors can be precisely controlled in each unit. The term "Phytotrons" was first applies after Fritz W. Went who built the Earhart Plant Research Laboratory, at the California Institute of Technology in 1949. These offer a wide range of environment simultaneously and very expensive with high degree of precision in environmental control facilities available for long – term research also. The large number of controlled units in phytotron also makes possible to investigate the interaction of various environmental factors on plants simultaneously. The building of phytotrons may become feasible only after the development of relatively low cost a conditioning systems and adequate lighting systems, utilizing high out – put florescent lamps.

Phytotrons are built in a few countries viz., U.S.A., Canada, Australia, France, Germany, Japan and states in Russia. The most modern phytotron was built at IARI, New Delhi in Novermber, 1998.

### 15.3.6 <u>Biotrons</u> :

It has facility to control the environmental factors, but designed to grow both plants and animals / insects. Animals are grown for producing meat profitably. Biotron facilitates the study of insects/ incidence on plant and plant behavior at desired controlled conditions. A biotron is present at University of Wisconsin, U.S.A.

### 15.3.7 <u>Climatron</u> :

The latest controlled environment installation is climatron in which there is precise control for both soil and air. The first climatron was built by Fritz Went at Botanical Garden in St. Lewis, Missouri, U.S.A has a large “Plexiglas” dome in which temperature gradients were established allowing (a) warm days warm nights, (b) warm days and cool night and (c) cool days and cool nights in different parts of unit. World’s most ultra–modern climatron is in Japan.

## 15.4 Case studies of Commercial Production

### 15.4.1 Commercial Production of Chrysanthemum:

Chrysanthemum is a short day plant which flowers only when the daily light period is less than critical period. Bud initiation takes place when the day length is about 12.5 hours the temperature requirement being around $16^0$ C. many cultivars of chrysanthemums must be vernalized before they respond to day length. About 3 – 4 weeks of exposure to chilling temperatures are needed for full vernalization. The optimum soil pH of about 6.5 is a must.

Commercial production of chrysanthemum through–out the year became possible by controlling the light as well as temperature in controlled environment. In summer when the daylight is longer, the plants are covered with black sateen (cloth) to shorten daylight to about 12 hours. If uninterrupted darkness is longer then seven hours, buds would invariably appear.

**Preventing or delaying bud initiation**

Depending upon market demand flowering is selectively prevented in chrysanthemum. Artificial light has been used for many years to delay flowering in chrysanthemum. Initially artificial light was used to the end of the natural daylight to extend the photoperiod. Later on, from 1940s, use of a flash of light near the middle of night was shown to be equally effective.

It is well known that the effectiveness of the night-breaks treatment is due to the conversion of Phytochrome, red form ($P_r$) to Far-red form ($P_{fr}$) which can be maintained at an effective level by intermittent lighting. Three seconds of light every minute for four hours is as effective at preventing flowering as 1.5 minutes of light every 30 minutes for 4 hours or even continuous light for 4 hours. The minimum practicable cycle would be 30 seconds at 200 Lux in every 10 minutes. The night period which is used for this treatment is between 11.00 p.m. and 3.00 a.m.

The use of cyclic night-break can save 80% of the power cost of lighting system. The application of this system depends upon (a) the cultivar, (b) the intended use and (c) the natural day length (the shorter the natural day, the night-break period).

**15.4.2 Commercial Production of Tomatoes :**

Tomato is a day neutral plant in which flowering shows no photoperiodic response. However, use of artificial light and proper temperature is beneficial in raising tomatoes in regions at higher latitudes such as U.S.A. and Great Britain, where especially in winter the day light is short, intensity of sunlight is less and temperatures are the lowest.

Especially during frosty days when natural conditions are totally unfavorable, growth rooms are used to raise tomato crop up to certain stage. The cost of producing complete crop with controlled environment is relatively high. In glasshouses artificial light is used to provide supplemental light and the temperature is maintained at about 16-18$^0$ C. the plants grow faster, come to flowering earlier and yield better when they are provided with 16 hours of 160 watt / m$^2$ and the day/night temperature of 26/20$^0$ C respectively. Usually the plants are grown on tiered benches to make best advantage of available heated space.

GROWTH CABINET

GROWTH ROOMS

UNIFORM PRODUCTION OF PLANT
MATERIAL THROUGH TISSUE CULTURE

PHYTOTRON FACILITY

POLYHOUSE

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**Lecture-16**

## CARBON DIOXIDE FERTILIZATION

**16.1 Definition**:

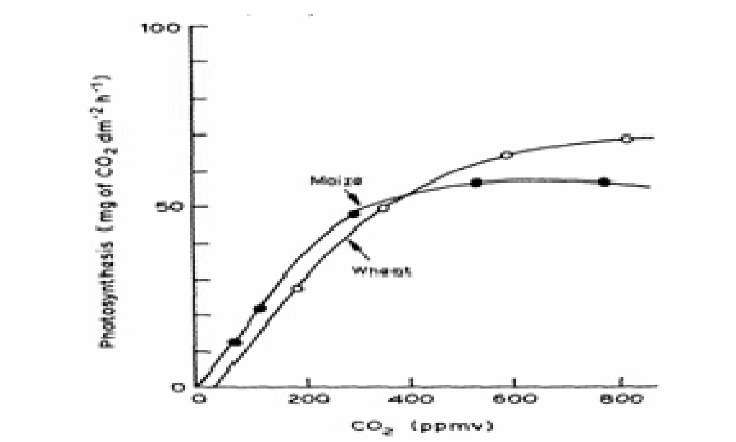
$CO_2$ fertilization refers to enhancing $CO_2$ concentration ambient to foliage (crop canopy) by artificial means.

**16.2 Concept**:

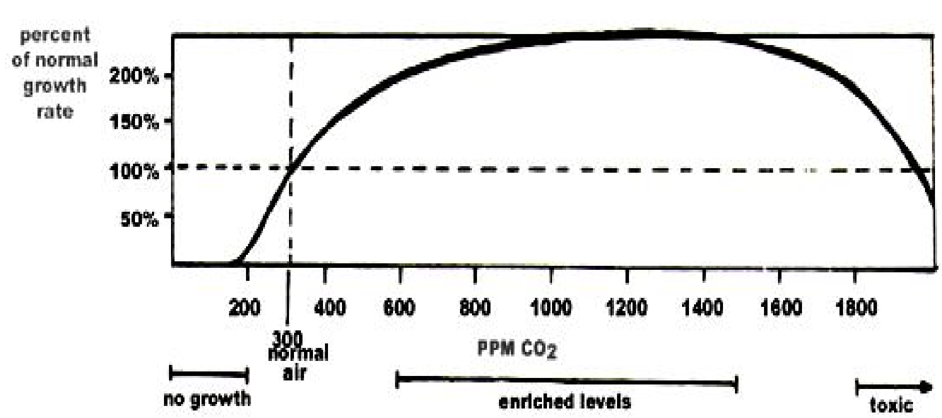
$CO_2$ is the most important rate limiting factor to increase the crop canopy photosynthesis. How ever, Photorespiration is common in all $C_3$ crops (like wheat, rice, Soybean, sugar beat etc.,) which are an important part of the world's food supply. In some of these plants photorespiration reduces as much as 50% of the net assimilation of $CO_2$ by photosynthesis. Therefore it is essential to find out the means to inhibit photorespiration to increase the crop yield.

Other equally important food crops – Corn, Sorghum, Sugarcane exhibit much less photo respiration. This difference can be explained in part by the fact that these species are $C_4$ plants carrying out $C_4$ photosynthesis. In this process the high concentration of $CO_2$ in the bundle sheath chloroplasts will selectively favor carboxylation rather than oxygenation and little phosphoglycolate will be produced.

Therefore, raising the $CO_2$ concentration increases net photosynthesis and decreases photorespiration greatly in $C_3$ plants.




The efficacy of $CO_2$ enrichment in increasing yields especially in closed environments such as Green houses is well documented.



From the above figure it is clearly understood that below 200 PPM, plants do not have enough CO2 to carry on the photosynthetic process and essentially stop growing. Because 300 PPM is the atmospheric $CO_2$ content, this amount is chosen as the 100% growth point. It is observed from the chart that increased $CO_2$ can double or some times more growth rate is also possible on most normal plants. Above 1500ppm the growth rate decreases and at 2,000 PPM, $CO_2$ starts to become toxic to plants.

**16.3 IMPORTANCE:**

1. $CO_2$ fertilization is an untapped modern agro technique which is not yet harnessed commercially for maximizing crop productivity. It is certain that the economic returns from the crops following this method exceed several folds when compared to the cost of the treatment. Though it is difficult to apply this technique to field grown crops it is not impossible.
2. Global atmospheric $CO_2$ concentration is on rise at the rate of 0.5 % per annum. Thus exploration of interactive effects of $CO_2$ and temperature has become an important area of research. $CO_2$ fertilization technique helps in doing such kind of simulation experiments to know the response of different crops at elevated $CO_2$ concentrations and temperatures.

**16.4 Sources of $CO_2$ generation**

1. Light stimulated $CO_2$ evolution from foliage in situ

   C3 plants generate $CO_2$ through **photorespiration**. Around 3,00,000 $C_3$ plants exists in the world

2. Release of $CO_2$ by animals and human beings in the process of respiration

3. Release of $CO_2$ from industries and automobiles.

4. **Soil respiration**

   a. Liming of acid soils increases $CO_2$ concentration

5. **Natural Carbon reserves**: Carbon reserves on the earth account to 67 x $10^{15}$ metric tonnes. World's largest reserves are found in Mississippi delta region and Rio Grande valley of Texas.

6. $CO_2$ is released from manure and compost pits in the process of **microbial decomposition**.

7. Pure forms of $CO_2$ like **dry ice** and cylinder $CO_2$ are some of the sources.

## 16.5 METHODS OF $CO_2$ FERTILIZATION

**In green houses** $CO_2$ can be made available through

a. Direct utilization of exhausts from combustion of fossil fuels

b. Production of pure CO2 and its distribution through perforated plastic pipes

**In field $CO_2$ can be made available through**

a. Mixing of carbonates reserves with water in trickle irrigation systems
b. Sowing of pellets of dry ice
c. Installation of plastic pipes and optimal release of $CO_2$ in crop rows
d. Spraying of carbonated water on to the foliage

## 16.6 EFFECT OF ELEVATED $CO_2$ ON CROP GROWTH, DEVELOPMENT AND YIELDS:

Doubling of $CO_2$ in the ambience of crops ( i.e addition of 300 ppm $CO_2$ to the existing $CO_2$ conc.) leads to a yield increase of 15% for CAM plants, 49% for $C_3$ cereals and 20% for $C_4$ cereals (Idso and Idso, 2000). The following are some of the striking responses of $CO_2$ fertilization.

a) Seed yield

i. Plant growth and seed yields of soybean were increased by 45% with 1200 ppm $CO_2$ level which was a result of more pods and seeds per plant borne on longer and larger branches.

b) Source and sink relationship:

i. A complete study on garden tomato, soya bean and maize exposed to supra normal $CO_2$ levels revealed cell volume changes and disruption of chloroplast structure by excessive starch grain accumulation. This problem is also observed in Cotton plant at 1000 ppm of $CO_2$ concentration.

ii. In this case, increased concentration of $CO_2$ has increased yield up to certain range only. Beyond that limit, the cultivars we are having at present are not in a position to utilise the benefit fully. This is because of increased strength of the source and a corresponding non-increase in sink drawing ability. This will lead to feed back inhibition and that is the reason for more accumulation of starch. Therefore if at all the benefits of $CO_2$

fertilization are to be harnessed completely there is a need to develop cultivars with increased source strength, translocation efficiency and sink drawing ability. A positive aspect in this context is that, an apparent genetic variation is present in almost every species or cultivar to increasing $CO_2$, for processes like net photo synthesis, growth rates, crop phenology etc.

c) Crop architecture:

   i. With increased $CO_2$ concentration leaf area increases. This will further enhance LAI and biomass in case of open canopy systems. While mutual shading reduces photosynthesis in closed canopy systems. Therefore, to get full benefit from this technique slight modification in crop architecture is to be achieved.

d) Change in crop duration

   i. Tomato plant grows more rapidly under enhanced $CO_2$ conditions. Its flowering date advanced, anthesis accelerated and early maturity of fruits is observed. Fruit size and number of tomatoes also increased with 10-70% increase in fruit yields. Thus more yield is produced in less time.

e) Accelerated maturity

   i. $CO_2$ fertilization has accelerated the maturity in Lettuce. A 150% increase in yield is observed in Grand rapids variety of lettuce.

f) Nitrogen fixation

   i. Symbiotic and Non symbiotic $N_2$ fixation is increased in an atmosphere enriched with 1000 ppm $CO_2$. This might be a result of more availability of carbon and changed C:N ratio.

g) Drought tolerance

   i. Wheat grown at 350 and 1000 ppm with and without water stress demonstrated that, increase in $CO_2$ completely compensated for water stress.

   ii. Similarly $CO_2$ enrichment has increased the root to top ratio in beans. This is a very important trait for legumes to impart drought tolerance.

h) Increased number of pistillate flowers

   i. In cucumbers, early maturity and higher yield is observed with $CO_2$ enhancement. This is because of increase in number of pistillate flowers.

i) Increased lateral branching

   i. Lateral branching was promoted in case of Carnation.

j) Flower size and quality improved

   i. Large flowers, early flowering, lengthy floral stalks, improved texture and quality of floral blooms, higher yields and shorter production periods was achieved with $CO_2$ fertilization in Roses, carnation, chrysanthemum, antirrhinum, petunias, snap dragons and geranium. With $CO_2$ fertilization it was found that Summer varieties could be grown in winter

**16.7 Limitations**

1. Extending large scale fertilization to open fields cause differences in leaf photosynthesis among plant species
2. Photorespiration presence or absence causes differences among species
3. Leaf orientation and architecture causes differences in diffusion of $CO_2$
4. Anatomical structures have relevance to certain type of biochemical pathways
5. Stomatal resistance to $CO_2$ diffusion on one or both surfaces of leaf
6. Differences in rates and types of dark reaction
7. Optimal response to enrichment depends on levels of light intensity, temperature, soil moisture, nutrient availability and crop varietal response
8. Transportation costs of pure or liquid or gas forms of $CO_2$ to places which do not have natural carbonate sources or places which do not have storage facilities

## 16.8 ECOLOGICAL MODELS

Extensive data on different types of ecosystems compelled the need of application of mathematics, Statistics and computers in ecology. This is to derive possible conclusions from these data and to compare the nature and direction of development of different kinds of ecosystems.

The main objective of such mathematical applications is, to describe detailed information on the structure and function of ecosystem. This will be achieved through equations and models in an abstract form. Such models are useful in comparison and management of different ecosystems.

### 16.8.1 CONCEPT

A model is a formulation that mimics a real world phenomenon by which predictions can be made. Ashby (1956) defined a model as homo-morphism of some real system which it represents.

An ecological model is a mathematical expression that can be used to describe or predict ecological processes or endpoints such as population abundance (or density), community species richness, productivity, or distributions of organisms (Rousseau et al., 2000).

Precisely, an ecological model is the quantitative description of the relationship between biological processes and the environmental factors that affect them. Models, in simplest form may be verbal or graphic (informal), but ultimately, must be statistical and mathematical (formal) if quantitative predictions are to be reasonably good.

### 16.8.2 DIFFERENT TYPES OF MODELS AND THEIR APPLICATIONS

Different environmental problems like flooding, upland soil and stream bank erosion, pollution from agricultural run off require the understanding of the natural processes leading to these problems. Mathematical models can be useful tools in simulating and simplifying these complex processes and help find solutions.

Agricultural models are mathematical equations that represent the reactions that occur within the plant and the interactions between the plant and its environment.

Some of such models are:

**A.Empirical model**

Empirical models are direct descriptions of observed data and are generally expressed as regression equations (with one or a few factors) and are used to estimate the final yield.

Examples of such models include the response of crop yield to fertilizer application, the relationship between leaf area and leaf size in a given plant species and the relationship between stalk height alone or coupled with stalk number and / or diameter and final yield in the sugarcane

**B.Dynamic Models**

These models predict changes in ecosystem status with time as a function of exogenous parameters.

Ex. 1. Models that predict the changing number of bolls on a cotton plant throughout the growing season.

2.The changing soil water content or temperature at a certain depth throughout the season.

**C) Phenological Models**

It is a broad class of models that predict crop development, from one growth stage to another. These predictions are generally based on accumulated heat units.

**D) Stochastic Models**

A probability element is attached to each output. For each set of inputs different outputs are given along with probabilities. Thus, we will get various possible alternatives for decision making

Eg: Weather variables and the probability of occurrence of insets, diseases and weeds.

**E) Mechanistic models**: These models explain not only the relationship between weather parameters and yield, but also the mechanism of these models (explains the relationship of influencing dependent variables). These models are based on physical selection. Therefore, they are sometimes referred as physical and physiological models.

Eg. Up take of Nitrogen by the root system from the soil. It is based upon the soil nitrogen content and the rate of solution flow to the root. Thus physical placement of the fertilizer with regard to the plant root system is important as well as soil and plant nitrogen transformation.

**F) Surrogate Variables**

These variables are calculated by the model and used to estimate the value of another quantity that the model does not directly calculate.

Ex. Calculation of dry matter production rate from the estimated transpiration rate by some modelers.

**G) Simulation models**:

Computer models, in general, are a mathematical representation of a real world system. One of the main goals of crop simulation models is to estimate agricultural production as a function of weather and soil conditions as well as crop management. These models use one or more sets of differential equations, and calculate both rate and state variables over time, normally from planting until harvest maturity or final harvest.

Models are now available for almost most of the crops. A list of them are given below

| S.No | Crop | Model name |
|---|---|---|
| 1 | Rice | *CERES –Rice, ORYZA-1, ORYZA-W |
| 2 | Wheat | CERES-Wheat, WTGROWS, APSIM – N wheat |
| 3 | Maize | CERES-Maize |
| 4 | Sorghum | CERES- Sorghum |
| 5 | Cotton | GOSSYM |
| 6 | Peanut | PNUTGRO |
| 7 | Potato | SIMPOTATO |
| 8 | Soybean | SOYGRO |
| 9 | Sugarcane | SUCROS , CANEGRO |

*__CERES__: CROP ENVIRONMENT RESOURCE SYNTHESIS

**APSIM**: AGRICULTURAL PRODUCTION SYSTEMS SIMULATOR

Computers need an instructional language to perform functions in a definite order.The more commonly used languages are

1. Fortran
2. CSMP (Continuous system modelling programme)
3. ILM (intermediate level model)
4. Pascal
5. C and C$^{++}$
6. JAVA

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