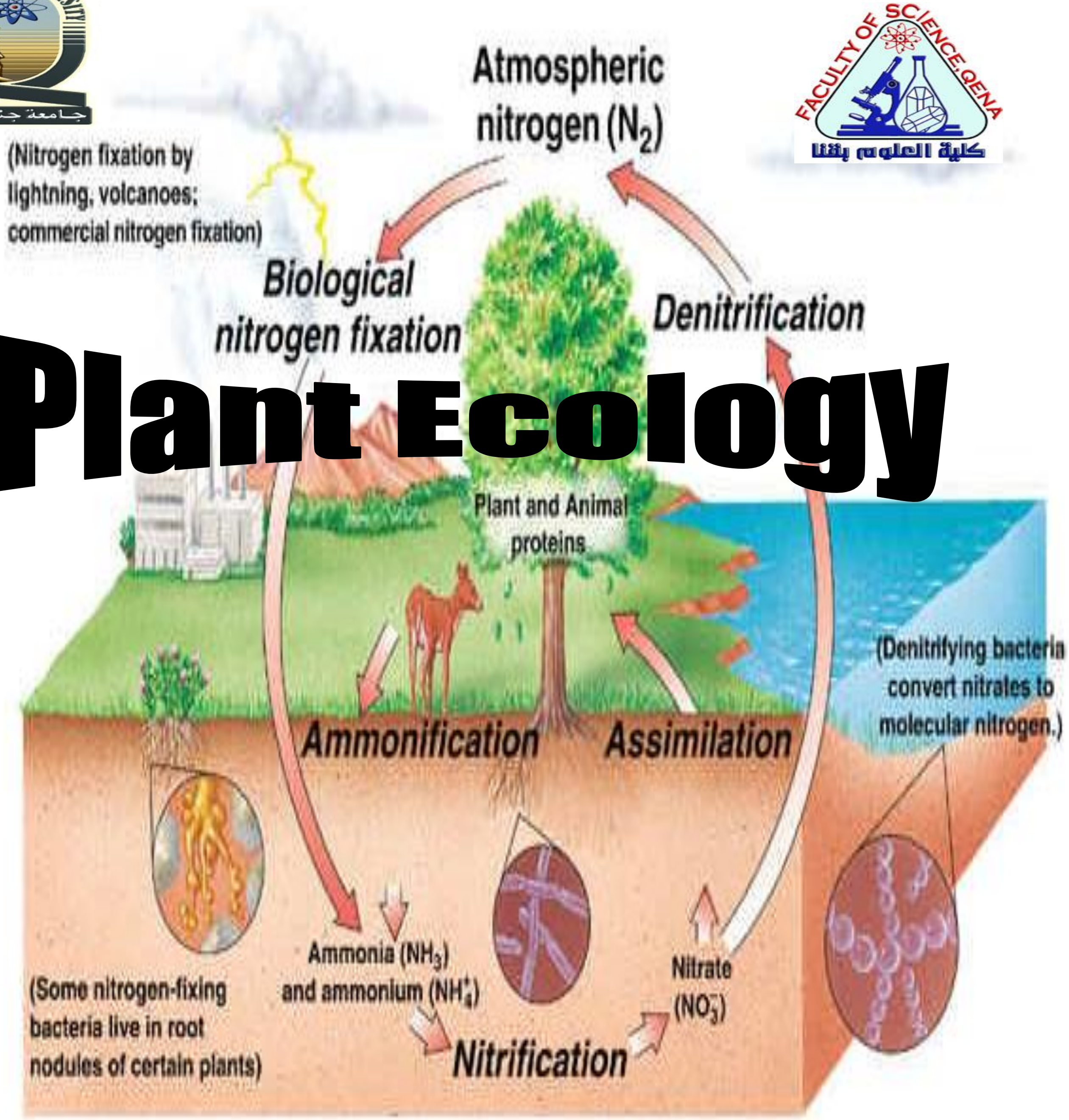
Plant Ecology



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PLANT ECO LOGY

- The term ecology is derived from the Greek words **Oikos** meaning home and logia which means the study of it.
- Ecology is: "the study of organisms in relation to their environment”.

The Organisms:

- It refers to all plants and all animals, including man. This means not only the larger organisms such as trees, grasses, deer, cows etc., but also any of the other lesser species in such environments. Some of these may be dependent on the larger organisms, some may be parasites, but all have relationships to each other and are using the resources available in their environments.
- The least of these such as bacteria and protozoa, contribute to the breakdown of dead organic matter and the release of its components to be used again, fix nitrogen or they may cause diseases.
- All the organisms in an environment are subjects for ecological consideration, all affect each other in some way and all have relationships to the environment.

The environment:

- The term "environment" includes everything that may affect an organism in any

1- Substances, such as soil and water
2- Forces, such as wind and gravity
3- Condition. such as light and temperature or
4- Other organisms.

- These factors may be studied or measured individually, but they must always be considered in terms of their interacting effects upon organisms and upon each other.
- The environment may be analyzed into a number of factors which may be grouped into three major categories:

1- Climatic (aerial), such as rainfall, and air temperature.
2- Edaphic (related to soil), such as soil moisture and soil temperature.
3- Biotic (related to other organisms) such as parasitism, herbivore and symbiosis.

- A fourth factor, which is not commonly recognized as being of universal occurrence, is the "pyric" factor which refers to the effect of fires caused by natural forces (such as , thunder storms) in forest and grass areas or by accidentally man-made fires.

The Habitat:

- It is the place where an organism or a community of organisms lives. A habitat has a particular set of environmental conditions such as a sand-dune habitat, salt-marsh habitat etc.

The subdivisions of ecology:

- Ecology is commonly divided into two types of studies:

l- **Autocology**: This branch deals with the study of individual organism or an individual species. The life history of the species as a means of adaptation to the environment is usually emphasized.

2- **Synecology**: Deals with the study of groups of organisms which are associated together as a unit. In other words synecology is concerned with populations and communities rather than with individuals. Useful subdivisions may be also based on the kind of environment or habitat such as:

1- Marine ecology: concerned with the organisms living in the seas and oceans.

2- Fresh water ecology: deals with organisms having rivers, and fresh water courses as their habitats.

3- Terrestrial ecology: which is the study of land plants in their relatively dry habitats. Ecology may also subdivide according to taxonomic groups such as: Animal ecology plant ecology, insect ecology etc.

THE ECOSYSTEM

- The whole complex of the plant and animals forming a community, together with all the interacting physical factors of the environment really form a single unit, which has been called the **ECOSYSTEM**.
- This takes into account all the living creatures in the community, from the fungi, bacteria and worms living in the soil to the mosses, caterpillars and birds up in the tree and all the factors of the environment, from the composition of the soil atmosphere and soil solution to wind, length of day, relative humidity and atmospheric pollution. etc.
- The ecosystem differs everywhere in the world e.g the ecosystem in tropical region differs than in alpine region but both have the same components. Any ecosystem consists of:

A Physical components, which are:
1- Climatic factors. 2- Edaphic factors.
B- Biotic components which are:
1- Plants 2- Animals. 3- Microorganisms. 4- Man.

All these components are in balance with each other every factor affect and effect in each other, the reactions between them are reversible and finally they are in balance state. Man represents the top on all the components of the ecosystem because he can affect and change them.

Biotic (living components). In most ecosystems the Kinds of organisms are numerous, and diverse and include producers, consumers, and decomposers.

A- Autotrophs or producers (plants).
B- Heterotrophs or consumers (animals).
1- First order: Consumers - herbivores.
2- Second order: Consumers - Carnivores, animals which eat the flesh of other animals.
3- Third order: Top Consumers (Carnivorous eat other carnivores)
C- Decomposers,(decompose dead organic substances) like fungi, bacteria and protozoa.

Characteristics of the ecosystems
l- The ecosystem consists of living (biotic) and non living (A biotic Factors or physical) components.
2- The relationships between the components of the ecosystem are always in balance (in two direction).Each factor affect and effect in each other, the reactions between them are reversible; finally they are in balance state.
3- The relationships between the components of the ecosystem are energetic i,e. The energy is not stable in the ecosystem.
4- The energy transfers between the components of the ecosystem in two ways:
a- between the living components through nutritional relations.
b- from living to non-living components through decaying (by microorganisms).
5- Energy transfers between the living components called the food chain. Energy transfers from living to non-living components called the mineralization chain.
6- The energy in the ecosystem transfers either in food chains or in mineralization chains through definite levels called energy levels.

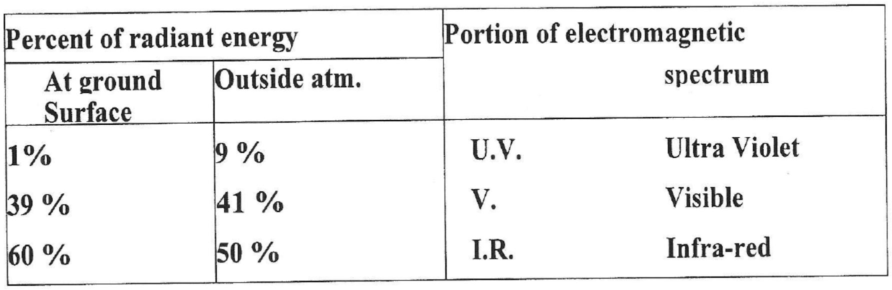
RADIANT ENERGY

- The sun's radiant energy (often called insulation) comes to the earth’s surface as "electromagnetic waves", the lengths of which are measured in microns (1\1000 mm) or mill microns, ($1/10^6$ mm). This energy (called the electromagnetic spectrum) includes those wavelengths of the "visible spectrum" that we called light and those that lie just beyond the visible spectrum, which we call "heat" or infrared radiation if slightly longer or "ultraviolet" if slightly shorter.

The ultraviolet (UV) light includes all wavelengths below 400 nm.
visible light (v.) includes wavelengths between 400-720 nm.
Infra-red (I.R.) includes wavelengths above 720 nm.

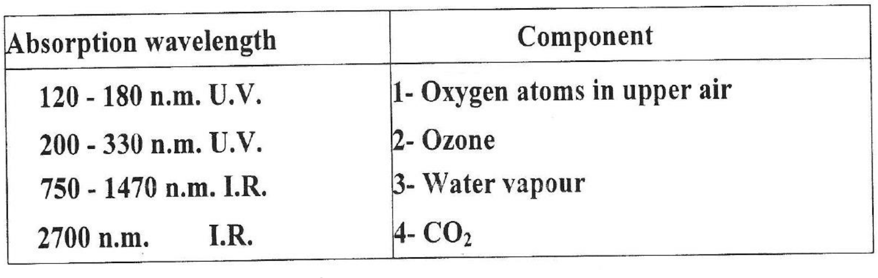
- The amount of solar radiation that falls on earth, at sea level, is much less than that received outside the earth's atmosphere, because of the absorbing effect of the different gases contained in the atmosphere around the earth.
- The amount of radiation reaching' the earth is always reduced because of absorption by the atmosphere (6 - 8 %) and sometimes as much as 40% may be reflected by clouds.

- The remainder reaching soil or water on the earth may be further varied by such factors as distance from the sun at different seasons, duration of radiation, and the angle of the rays with the earth's surface.
- The last determines the amount of air through which the rays pass, modifies the amount of reflection and absorption, and likewise controls the amount of energy falling on a unit area simply by spreading or concentrating a given amount of energy over more or less space.
- The reduction in radiant energy, **caused by the earth's atmosphere is** as follows: Percent of radiant energy portion of electromagnetic



Percent of radiant energy		Portion of electromagnetic spectrum	
At ground Surface	Outside atm.		
1%	9 %	U.V.	Ultra Violet
39 %	41 %	V.	Visible
60 %	50 %	I.R.	Infra-red

- For these reasons, ultra-violet and infra-red radiation is reduced much more on a cloudy day than on a clear sunny day. This is also the case for high mountains where ultraviolet radiation is much more abundant than at lower levels in the same place.
  - In its passage down through the atmosphere, **the depletion of solar energy results chiefly from selective absorption by the constituent gases and water vapour, from the scattering by molecules of air and small solid and liquid particles, and from reflection outward to space by larger particles and cloud surfaces.** واستنزاف نتائج الطاقة الشمسية أساسا من الامتصاص الانتقائي من الغازات المكونة وبخار الماء، من تشتت جزيئات الهواء والجسيمات الصلبة والسائلة الصغيرة، ومن انعكاس إلى الخارج إلى الفضاء من قبل الجسيمات الكبيرة و اسطح الغيوم. The constituents of the atmosphere that take a significant part in the absorption of solar radiation are the following:



Absorption wavelength	Component
120 - 180 n.m. U.V.	1- Oxygen atoms in upper air
200 - 330 n.m. U.V.	2- Ozone
750 - 1470 n.m. I.R.	3- Water vapour
2700 n.m. I.R.	4- CO_2

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The effect of the various bands of the solar spectrum on plants is as follows:

Band W.L. in n.m.		Effect on plants
1000 - 3000 n.m.	I.R.	No specific effect on plants, when absorbed by the plant, it is transformed into heat without affecting the biochemical processes.
720 - 1000 n.m.	far-red	Have specific elongation effect upon plants. Also affects photo-periodism, seed germination, control of flowering and coloration of fruits.
610 - 720 n.m.	red	Strongly absorbed by chlorophyll,therefore generates strong photosYnthetic activity.
510 - 610 n.m.	green	Have little or no effect on photosynthetic,activity.
400 - 510 n.m.	Blue violet	The region of strongest and yellow pigment absorption, strong photosynthesis.
315 - 400 n.m.	U.V.	Plants become shorter and leaves thicker (affect the form of plant).
280- 315 n.m.	U.V.	Detrimental to most plants Rapidly
Less than 280 nm.	U.V.	kills the plant.

CLIMATIC FACTORS
I. TEMPERATURE

- As a result of the absorption, of shorter wave lengths from the sun's radiation by the earth’s atmosphere, most of the radiation falling on earth has a heating effect' This radiation, when hitting the surface of solids (like the soil) or liquids (like the seas & oceans) their particles are set in rapid vibration, resulting in a heated condition' The earth's surface quickly reradiates much of the heat it receives from the sun resulting in a heating effect upon the atmosphere.

- The heating effect of the air layer just at the soil surface is the result of the process of "conduction". The heated air layer decreases in density and starts to move upward and also horizontally to cooler areas of the air mass above and around. This process of transfer is called “convection".
- The heated condition of a solid or liquid body, and of the air, is expressed by either one of two terms:

1- Heat which is a quantitative term used to refer to the quantity of energy received by or contained in this body' The unit of measurement of heat energy is the "gram calorie" which is defined as the quantity of energy that can raise the temperature of one gram of water from 15 to 16^{o}C Radiation may therefore be expressed as gram calories per square centimeter per hour.

2- Temperature, which is a term used to refer to a particular level or degree of molecular activity (energy). This is a qualitative term as it expresses a condition rather than a quantity because a fewer gram calories are required to raise the temperature of a small body of water through the same number of degrees (that is to the same temperature level) as would be required for a large body

Temporal variations in temperature:

- The amount of heat received from the sun fluctuates owing to the momentary passing of clouds, the daily and seasonal phenomena. As the sun rises in the morning, the earth’s surface begins to gain more heat than it loses by re-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. This equilibrium is maintained until radiation begins to weaken during the afternoon.
- After the sun sets, the earth's warmed surface continues to give up its accumulation of heat to the atmosphere by radiation, and since it receives no more of this energy from sun, its temperature declines steadily during the night.
- This nocturnal loss of heat is accelerated by the cooling effect of evaporation from the soil, so that the soil temperatures characteristically drop below air temperatures, with the minimal surface temperature occurring just before sunrise. Because the daily maxima are higher and the nightly minima are lower, the surface temperature of exposed soil fluctuates more widely each 24-hour period than doe's air temperature.

Importance of temperatures to plants:

- Temperature is like water in its action upon plants. It has more or less to do with nearly every function, but as a working condition, not as a material. All the chemical processes of metabolism and also many physical processes such as diffusion, precipitation, coagulation of cell proteins etc. are dependant upon temperature and accelerated by its increase up to an optimum. with a decrease in temperature to a certain minimum, growth is retarded; at lower temperatures, cell division and photosynthesis are also decreased and, at a still lower minimum respiration stops and death of the plant takes place. Therefore, temperature is not only necessary for life processes but also furnishes the energy for some of them. Radiant energy' for example, is absorbed in photosynthesis and set free in respiration.

- The habitat plays an important part in determining the influence of temperature upon each species. A particular species has been accustomed for countless generations to certain extremes of heat and cold as well as to certain seasonal temperatures. The temperatures beyond these extremes decrease the plants activity.
- Temperatures favorable and unfavorable to plants: (cardinal temperatures) plants are adapted to a wide range of temperature. Some species are able to grow in extremely low or extremely high temperatures. In fact, some of the lower forms of plant life such as algae may grow and fruit in arctic waters at temperatures below zero.
- Conversely, numerous algae and bacteria thrive in hot springs at temperatures as high as 77^{o}C and a few fungi can endure temperatures of 89^{o}C plants are subjected to a considerable range of temperature during their period of growth. They grow only when the temperature remains within certain limits, and mature and die became dormant when it falls to low or too high levels. There are three critical temperatures in the life of the plant which affect its state of functioning. These are the optimum, the minimum and, maximum temperatures. These temperatures are known as "cardinal temperatures”.

1- The Optimum temperature:

- The temperature at which a plant functions best is called the optimum. optimum temperatures for the various physiological processes, e.g photosynthesis, respiration, and reproduction do not coincide, that for respiration, for example, being much higher than the optimum for food manufacture. Therefore, it seems clear that the ecological optimum or temperature at which the plant as a whole develops best is never a mere point but a range of several degrees at least. As the chemical and physical processes within the plant are quickened by a favorable temperature, demands for water and nutrients are also increased.

2- Maximum temperatures:

- The maximum temperature that can be tolerated without injurious effects in the plant, often resulting in death, varies greatly with the species. It seems to be an inherent quality of the protoplasm gained through the evolutionary adaptation of every plant At high temperatures, the growth rate of plants rapidly falls and soon a point is reached beyond which the plant dies. At about 40oc, changes begin to occur in the protoplasm that are inimical to the life of the plant, and most plants fail at temperatures between 45 and 55^{o}C.

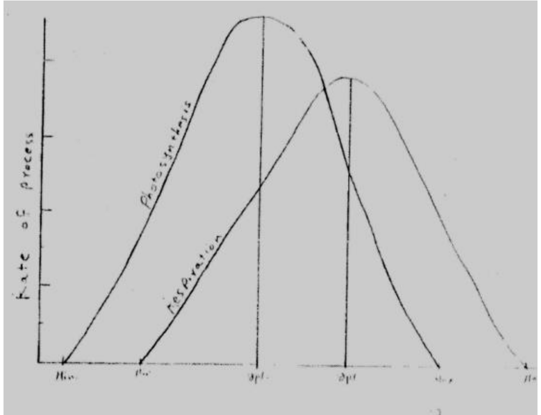
- Like minimum temperatures, maximum ones vary widely with different species. Some tropical plants carry on their life processes at temperatures so high that most plants if subjected to them would die in a very short time. Furthermore' a plant withstands extremes of heat and cold much better in some stages than in others.
- It is least resistant in the active condition when the tissues are filled with water and most resistant in the resting states typical of spores, seeds, corm etc. when dry, seeds can endure, temperatures above 100°C although they are readily killed at 70oc if water soaked. Certain species of yeast have been shown to be capable of enduring a temperature of ll4°C when dormant, and bacteria in the spore condition are able to withstand temperatures of 120 to l30°C.

3- Minimum temperatures and freezing:

- The minimum temperature at which any plant can continue activity is approximately the freezing point of water. Some arctic and alpine plants may produce their flowers after coming up through banks of conifer and may continue to flourish, although the temperature falls freezing every night. The activities of marine algae at temperatures below zero have been observed.
- On the other hand, many tropical plants are retarded in growth at 20°c and some are frequently killed at 20°C. The minimum temperature, moreover, varies greatly at different times of the year and with different conditions of the plant as well as its previous experience with low temperatures. The chief difference lies in the amount of water the plant contains. The watery leaves and herbaceous stems of plants of temperate climates, for example, are usually killed by an exposure to l00°c and frequently at temperatures 2 to 4°C above freezing,
- The drier seeds and inactive ground parts resist the long continued effect of temperatures of -30 to -40oc; dry seeds being uninjured by -193 to -250°c. Death by winter killing or cold at any time is usually a matter of desiccation and its attendant results brought on by low temperatures.
- Since the cell sap always contains solutes that depress its freezing point, only temperatures lower than 0°c cause the water to freeze. Plant tissues can be under cooled several degrees below the freezing point and warmed up again without injury provided no ice formation occurs. A plant or its growing parts (buds, cambium etc') are not necessarily killed, even though they are solidly frozen.
- On the arctic coast of Siberia, some plants are struck by winter climate and are exposed to extremely low temperatures (-46°C) while still in the flowering stage. In spite of this, they began again to blossom quite unharmed upon the recurrence of warm weather'

Cardinal Temperatures for Physiologic Processes:

- Cardinal temperatures differ for the same function in different plants. For example, the minimal temperature for growth in melons, sorghums, and the



date palm lie between 15 and 18°C, and the corresponding value for peas, rye, and wheat lie between -2 and 5°C.

- The maximal temperature for growth in boreal shade plants is not many degrees above freezing, but a species of ***Opuntia*** was observed to make growth when its tissue temperature was 56.5°C and the air temperature was 58°C.
- Certain arctic marine algae and the snow algae complete their life cycles in habitats where the temperature never rises significantly above 0°C, whereas hot-spring algae may live in water uniformly as hot as 77°C. Because of evolutionary adaptation it is generally true that the warmer the native habitat of a species the higher up the temperature scale its cardinal temperatures lie.

- Different functions of the same plant may have different cardinal temperatures. In many, if not most plants, the optimal temperature for photosynthesis is distinctly lower than the optimum for respiration. In the white potato the rate of photosynthesis rises to a sharp maximum at about 20°C, but respiration at this temperature is only 12% of its maximum rate. With an increase to approximately 48oc respiration reaches its optimum, but the photosynthetic rate has declined to zero by this time. Because both growth and reproduction depend upon a more rapid rate of accumulation than of oxidation of organic compounds, plants are at a disadvantage whenever the temperature rises above the optimum for photosynthesis.
- This is believed to be the explanation for the facts that peaches, apples, white potatoes, etc., do not accumulate normal food reserves when planted below certain altitudinal or latitudinal limits, and those anthocyanins, which are usually associated with abundant sugars, fail to develop at high temperatures. This photosynthesis-respiration relationship may prove to be of considerable importance in setting the lower altitudinal and latitudinal limits of many plants. Quite possibly the more rapid rate of carbohydrate accumulation observed in certain crop plants as temperatures decline at the end of summer is in part at least a result of temperature control of the photosynthesis-respiration relationship.
- Various organs of the same plant may have different cardinal temperatures for the same function. Roots, the temperature of which follows that of the soil' appear to have lower (i.e. threshold minimal) temperatures for growth than do shoots. In many plants of temperate regions the roots continue growing as long as the soil is not frozen, although in general the roots of most plants in temperate climates become relatively inactive for at least a part of the winter. Because of definite and often different temperature requirements of roots and shoots, the relations between soil and air temperatures have a pronounced effect upon the welfare of certain species.
- Cardinal temperatures vary also with the age of the plant, with its physiologic condition, with the duration of particular temperature levels, and with variations in

other environmental factors. Strictly speaking, then, a cardinal temperature is a range rather than a fixed point on the temperature scale, and with plants growing in natural environments, it follows that the optimal temperature conditions for the successful completion of the life cycle embraces a range set by particular maxima and minima which may limit development only at one or two points during the cycle. Thus the temperature requirement of different functions at each stage of development must lie within the variations in temperature which prevail during the season corresponding to that stage of development. At each phase of development there is, for the organism as a whole, an optimum range which is most conductive to the harmonious interaction of all physiologic processes.

Beneficial (Stimulating) effect of Low Temperatures:

- Many plants native to cool and cold climates must each year undergo a rest period that is not enforced primarily by low temperatures. After growing vigorously for a time they become dormant even though external conditions remain favorable for growth.
- Ordinarily this dormancy is broken only by temperatures below about 5 to 8^{o}C, the effect of short periods of exposure below this level being cumulative, yet susceptible of being nullified by subsequent high temperatures.
- If a plant is moved too far in a pole-ward direction, its chilling requirement is satisfied early in winter so' that growth is resumed before the end of winter. If moved too far in equatorial direction the chilling requirement may not be met by the end of winter- the dormant buds will not open promptly with the arrival of warm weather and the development of leaves, flowers and fruits is repressed, e.g. peaches require 400 or more hours of temperature at or below 7^{o}C, the length of time varying with the variety.
- Winter stimulation accordingly has been found to set the lower altitudinal and latitudinal limits of profitable culture of these plants. An example of this is illustrated by trials to introduce pistachio trees into the coastal Mediterranean area of the western desert in Egypt. The trees could give vigorous and healthy vegetative growth but failed to flower and subsequently to give a crop.
- This was primarily due to the unfulfilled chilling requirements of the plants since the temperature in winter seldom falls below 7^{o}C. Laboratory experiments could prove this to be the case. Low temperatures are often necessary to stimulate the formation of flower buds. In ***Senecio***, for example, the flower buds are not formed if the plant was kept under a temperature above 15.5oC. In most herbaceous plants the temperature level necessary to stimulate the formation of flower is lower than that favors rapid flower development, whereas very high temperatures repress flowering.
- The seeds of many plants of cold regions require chilling under moist conditions for a period after apparent maturation if they are to germinate vigorously. The common practice of supplying these conditions artificially is called “**Stratification**" and

temperatures varying from 1 to 2^oC for one to several months are used, depending on the species.

- Certain plants, although they do not have a rest period the breaking of which requires a low temperature, need low temperature during or shortly after germination in order to complete their life cycles quickly. For example, winter wheat sown in spring does not flower before the plants are subject to the following dry summer, but if soaked grains are subjected to a temperature just above freezing for a period, it can be sown in spring and a crop quickly produced.
- Since cold treatment is effective through promoting the formation of an essential metabolite, the stimulus derived from chilling is retained even if the seed is subsequently dried. Thus, if seed wheat is moistened to 50% of the dry weight, then chilled at 2^oC for about two weeks, it can be dried again and sown many weeks later.

Cold (Chilling) Injury and Frost (Freezing) Injury

- The migration of plants from their ancestral environment of the seas onto the land necessitated marked adaptation for enduring the wide variations in temperatures that characterized the newer environment. Although there is no region on earth which is so cold or, so hot but that some plants live there, plant adaptations are not so perfectly adjusted but that temperature extremes frequently cause injury or death.
- Moreover, the absolute extremes that result in the immediate death of protoplasm are much farther apart than those extremes that are determined by inhibiting growth and other functions. When temperature drops below the minimum for growth a plant' becomes dormant, even though respiration and sometimes photosynthesis slowly continue.
- **Chlorosis** likewise may result from such chilling. With further loss of heat a point is usually attained below which the protoplasm is fatal injured. Molisch (1897) has called low temperature damage, in the absence of freezing, "**Chilling Injury**" as opposed to "**Frost Injury**" caused by freezing. Three main phenomena appear to be involved in killing by low temperature:

a) proteins may be precipitated directly, especially in plants that are killed before temperatures drop to the freezing point of water.

b) b-At lower temperatures, intercellular ice commonly forms, drawing water out of the protoplasts. This causes a dehydration which, below a certain critical temperature or after a prolonged period, allows irreversible precipitations in the protoplasm. Possibly mere deformation of the shrinking cell may be lethal. Also, when the ice crystals melt rapidly the cell walls may expand more rapidly than the protoplasts can swell, and thus may tear the two apart.

c) Rapid freezing causes ice to form within the protoplasts. This ice formation is nearly always fatal presumably because crystal growth disrupts protoplasmic organization. The ability of plants to endure low-temperature extremes varies widely among species.

- Certain plants of tropical affinity such as cotton, sudan-grass etc. are injured to exposure by temperatures which are low but yet above the freezing point (5°C) Other plants are not injured until they are frozen; still others native to cold climates can endure periods when the tissues are frozen solidly and the temperature drops to -62°C.
- The freezing point of plant sap, because of its solute content, usually lies several degrees below 0oc, but certain plants, mostly cryptogams and seeds, cannot be frozen at any temperature (even -270°C)rand 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. Among trees seedlings are commonly more sensitive to cold than older plants, but with grasses the relationship may be reversed.
- Even for the same plant, the frost killing temperature may vary widely with the manner of the temperature change, the season and the physiological state of the plant. Killing may occur at higher temperatures if the freezing is rapid, rather than gradual. Greater injury to the plant may occur after long continued freezing than that after short freezing periods at the same temperature.
- Injury may also occur after two or more freezing's that failed to injure the plant in one. Freezing- some plants that survive the cold in winter may be killed by a very slight freezing during spring.

Adaptive resistance to low-temperature injury:

The degree of injury that plants suffer from low temperature depends upon:

1- The degree and duration of minimum temperatures

2- The suddenness of change.

3- The previous physiologic conditioning by the level of mineral nutrition, moisture content of tissues, and the length of day.

4- The adaptational characteristics.

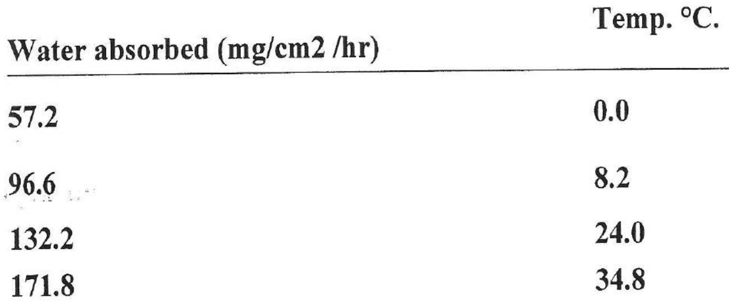
- Adaptations that permit plants to endure low temperature successfully are mostly protoplasmic. The principal exception to this is that plant organs the surfaces of which are covered with a waxy bloom or with dense pubescence can endure freezing temperatures for a relatively long time without ice formation inside the tissues' Also, small cells are correlated with old resistance' Temporary protoplasmic adaptation affording a measure of immunity to low temperature injury is called "**hardening**".
- It can be induced artificially by most conditions that result in a sudden checking of growth, especially by chilling to within a few degrees of freezing for at least a few hours, or by drought. The lower the temperature used in hardening the greater the resultant degree of cold resistance.
- Glass house grown seedlings are generally hardened by placing them temporarily in a cold frame and watering them but lightly. In irrigated orchards the trees can be hardened against early autumn cold temperatures simply by withholding water. These

practices lower the injurious temperature level a few to many degrees, depending on the species and on the duration of the hardening period.

- If a plant endures the first frost without injury, its resistance increases with each subsequent exposure. Several interrelated physiologic changes are known to take place during hardening. The protoplasm develops a low structural viscosity and therefore is better able to accommodate deformation.
- The free water content decreases, and at the same time soluble proteins and sugars increase. Both changes, which are especially pronounced in aerial organs, lower the freezing point of tissues. The importance of abundant carbohydrates is shown by the fact that defoliation or any other condition which prevents their accumulation renders plants more susceptible to cold injury.
- In general, small increases in osmotic pressure of the cell sap are associated with considerable margins of resistance to low temperature. Most of the factors that make a plant frost resistant also render it less susceptible to drought injury.

Winter Drought Injury:

- On account of the slowness with which the temperature of the soil changes, the temperature of the air is alternately higher and lower than that of the soil. At these times during the cold season when air temperature is the lower, cold injury is the chief hazard to plants; but when the air becomes warmer than the soil, plants have great difficulty in replacing water lost by the shoots in transpiration.
- With a drop in temperature from 25 to 0°C, the viscosity of water is doubled. Therefore even when there is an abundance of growth water, low temperature greatly reduces the ability of the soil to supply water to the roots, as shown in the following table showing the amount of water absorbed by a pottery (porous) surface at different temperatures:



Water absorbed (mg/cm2 /hr)	Temp. °C.
57.2	0.0
96.6	8.2
132.2	24.0
171.8	34.8

- The optimum temperature for absorption by roots is generally around 30°C or higher, and soil temperatures in the root horizons are usually lower than this even in summer. The fact has long been known that plants can be wilted by cooling the soil about their roots.
- It has been shown experimentally that cold soil induces the same structural modifications as drought, thus demonstrating the correctness of the application of the term physiologic drought to this phenomenon.

High temperature Injury:

- Aside from its role in desiccation, and in bringing about a dis-balance between respiration and photosynthesis the high temperature can injure and kill the protoplasm. When temperature rises above the maximum for growth, the plant enters a quiescent state, sometimes accompanied by **chlorosis** and, with further heating, a lethal level is eventually attained.
- The thermal death point usually is a few degrees above the optimal temperature for growth. It is believed by some that the first decrease in physiologic activity above the optimum is due to an inactivation of enzymes. The principal adaptational features which protect plants against high temperature injury are:
  1. Thinness of leaf blades coupled with high transpiration, which prevents leaves exposed to the sun from becoming more than about 5oC warmer than air, and possibly account for the fact that they are seldom injured by heat.
  2. Vertical orientation of leaf blades which always reduces the tissue temperatures at least 3 to 5°C below that of leaves turned at right angles to sun's rays.
  3. Whitish colour of surfaces which reflect rays that would otherwise be absorbed and become heat energy.
  4. A covering of dead hairs or scales which shades living cells.
  5. A thick corky bark which insulates the phloem and cambium.
  6. A low, moisture content of the protoplasm, and a high carbohydrate content.
- Any development of resistance to frost or drought usually involves an increase of resistance to heat injury.

Temperature efficiency:

- Because heat energy increases the kinetic activity of molecules, the higher the temperature the more rapid is the rate of chemical reaction and, consequently the physiologic processes. The ratio of a rate of reaction or function at a given temperature to its rate at temperature 10°C lower is called the "**temperature coefficient**" and is designated by Q.
- The temperature coefficient usually varies between 2 and 3, depending on the particular reaction, but in a single complex organism function the coefficient varies from zero above and below the maximum and minimum temperatures' respectively, to very high values on approaching the optimum temperature.
- Ecologists have long been interested in evaluating temperature data in terms of efficiency in allowing plants to grow and reproduce vigorously, but the problem is very complex.
- Trials have been made in several directions to reach a quantitative evaluation of temperature efficiency to plants. Coefficients and indices are calculated from the temperature records obtained from meteorological stations in the field. Some of these indices and coefficients are as follows:

The plant zero:

- The activity and growth of any plant depend upon its receiving the requisite amount of' heat during the growing period. The influence of temperature on the size of the plant is very great because of its control over growth. The sum of the temperatures that act upon a plant is of the first importance in determining its general appearance.
- The effect may be produced either by temperatures that are more or less constantly too low or by shortness of season, which is equally effective in reducing the total amount of heat available for the use of the plant. Since temperature is one of the most influential of all climatic factors affecting plant growth, it has received much attention in connection with crop production.
- In spite of much study, very little is known about the relationship between air temperature and the development of any crop. Could the heat requirement of various crops be stated in terms of temperature and times, it would be of immense importance to agriculture.
- For many years, an effort has been made to determine the total of the affective heat units necessary to grow various crops to maturity. Since all temperatures below the minimum are ineffective in promoting growth, it was first necessary to select a plant zero, i.e. a temperature above which growth begins.
- Since this varies for different crops and, to some extent, with other conditions such as latitude and altitude, length of day, etc. different plant zero points have been suggested. This is about 3°C for spring wheat, 13°C for corn, and 17°C for cotton. It varies but little, regardless of where the crop is grown.
- The plant zeros most used, however, have been 43 and 40°F (4.5°C) and three summation processes have been employed to determine the effect on plant growth of temperature sums above this point.

Remainder Indices:

- By the process of remainder indices of temperature efficiency for plant growth; which has been used most frequently, all mean daily temperatures above the plant zero during the life of the crop have been added together. This would be 100°F for one day with a mean temperature of 53°F (plant zero of 43°F). In this way, the RI = Mean daily temperature - plant zero.
- However, with terrestrial plants this method of expression is subject to the criticism that normal functioning may be more closely governed by day than by night temperatures and in other plants, nocturnal temperature levels are very critical. The mean temperature values obviously cover up the differences in day and night temperatures.

Exponential Indices:

- Exponential indices of temperature efficiency for plant growth are based on the fact that the physiological processes of plant metabolism are chemical and physical in nature and follow the principle of **Vantt Hoff and Arrhenius**, which states that the chemical reaction velocity approximately doubles for each rise in temperature of (10^{o}C).

- On this basis, indices of temperature efficiency have been calculated, assuming that general plant activity occurs at unity rate when the daily mean temperature is 5^{o}C (plant zero) and that this rate is doubled with each rise of 10^{o}C in the daily mean. Thus, with a daily mean of 15^{o}C, the rate becomes 2, with a mean of 45^{o}C it becomes 4, etc,.
- Hence, the index efficiency "I" may be found for any temperature "t" by substituting in the formula:

$$I= 2^{[t-s/ 10]}$$

e.g. a temperature of 35^{o}C gives $I = 2^{3} = 8$

- Increasing temperature is not accompanied by increased growth through the range of the growth rate from the minimum to the maximum. Instead of the growth of wheat, for example, doubling at 100^{o}F that which occurred at 82^{o}F it actually decreases.
- An optimum can always be found above which the previously increasing growth rate begins to decrease.

Physiological Indices:

- Physiological indices of temperature for plant growth take into account the optimum temperature. The method is of such a nature that both low and high temperature values give efficiency indices of zero, and intermediate temperature values give indices whose graph shows a well defined maximum.

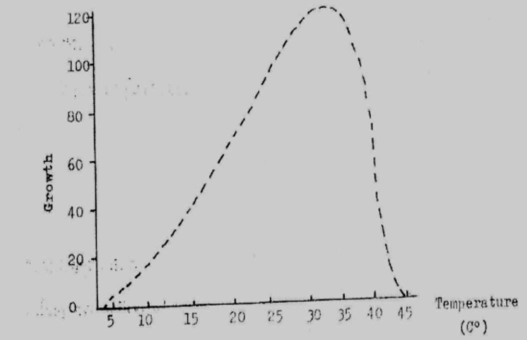


Fig.: Variation of the growth rate of corn seedlings with temperature.

Effect of temperature on the geographical distribution of plants:

- Temperature is the most important factor in determining the general distribution of vegetation. Grassland forest, and desert all occur in each of the great temperature zones of the earth, but the component species of forest, for example in each zone is different. Temperature also is the most important factor in determining the distribution of crop plants. The northern limit of the successful commercial production of cotton is determined almost entirely by temperature conditions.
- The isotherm of 10^{o}F for the daily minimum temperatures of January and February, for example, coincides, in general, with the northern boundary of winter wheat culture in the northern hemisphere. This boundary is taken as the line beyond which spring wheat is grown more commonly than winter wheat.
- Potatoes, on the other hand, give the highest yield in regions with lower summer temperatures, since tuber growth is retarded by high temperatures. Temperatures of the growing season alone limit the growth of certain crops such as corn, while other, e.g. grapes, and are limited by the temperature of the non-growing season as well.

Temperature and plant diseases:

- The ability of a parasitic fungus to gain entrance into as well as to develop within a host organism is often strongly conditioned by temperature. For example, at temperatures below 13ºC the seedlings of most strains of maize become very susceptible to disease whereas flax becomes susceptible to ***Fusarium*** wilt only at temperatures above 14ºC. Host plants commonly extend into climates where temperature restricts their parasites and it is often possible to subject a diseased plant to temperatures lethal only to its parasites.

Temperature and Transpiration:

- Transpiration, which is the loss of water vapour from the plant leaves through the stomata, increases directly with the magnitude of the difference in temperature between the leaf surface and the adjacent air. Temperature also changes the ratio of cuticular to stomatal transpiration.
- Therefore, the higher the temperature the greater cuticular transpiration is. Thus, at a temperature of 49ºC the nocturnal (night time) rate of transpiration in ***Helianthus annuus*** was observed to rise to 91% of the diurnal (day time) rate, even though the stomata remained closed at night.

II - LIGHT

- Wavelengths between 750 and 400 mp are called light or "luminous energy" because these wavelengths alone out of the total range of wavelengths of radiant energy can be seen with the eye. This is likewise almost the entire range of wavelength involved in photosynthesis, and green plants grow normally only when exposed to a combination of most of the wavelengths in this range. Approximately 50 oh of the total energy of solar radiation lies within this narrow range. When sunlight is passed through a prism it is dispersed as follows:
- All these colours making up the spectrum affect photosynthesis, but yellow and green are utilized very little, the principal wavelengths absorbed are in the violetblue and orange-red regions. Phototropism is governed chiefly by blue-violet wavelengths.

Units of measurement of lisht:

- We learned before that radiant energy (which includes both invisible radiation and light) is measured in terms of Gram calories or calories.
- 1 gram calorie =4.18 joules =41.8 x L06 ergs.
- Measurement of the intensify of light alone is based on the illumination produced by a ”standard candle”.
- I foot-Candle F.C. = light intensity at 1 foot from a standard candle.
- 1 Lux (meter-candle) =The intensity of light at 1 m from a standard candle.

- 1 foot-Candle = 10.764 L.
- By common agreement of world scientists the lux has been accepted as the standard international unit for expressing light intensity.

The role of Infra-red radiation:

- Infra-red light comprises all the radiations of wavelength greater than 800 nm. And these. are invisible. Here we are considering only the near infra-red, i. e. of wavelengths between 800 and 2000 or 3000 nm. A little more than half of the solar radiation is in this region, most of the remainder being in the visible range. Incandescent lamps, which are the most common artificial light sources, radiate about nine-tenths' of their power as infra-red radiation. It is therefore important to know the particular action of these radiations, both for plants grown in natural daylight and for those which are bound to increase in number cultivated wholly or partially in artificial light.
- In practice, the chemical activity of infra-red radiation is not strong enough to disturb chemical structural it causes oscillations of the atoms around their positions of equilibrium without destroying the molecules. These oscillations are solely heat manifestations and we may expect that the special action of infra-red will be to heat up the bodies that absorb it. on the contrary, although, by the same process' the visible and ultra-violet also have a heating effect on the substances that absorb them, these radiations can, incertain cases, particularly the ultra-violet, transmit to the molecules enough energy of excitation to make chemical reactions possible'

It is necessary to distinguish two principal zones in the infra-red:

1. The wavelengths shorter than 1400 nm which represents the major part of the solar infra-red and is relatively little absorbed by the leaf'
2. The wavelengths greater than 1400 nm relatively less abundant in solar radiation

- But proportion ately to the visible, very abundant in the radiation from incandescent lamps. This zone is strongly absorbed by leaves' As a result, when plants are cultivated under incandescent lamps, the action of the infra-red is inordinately increased for two reasons:
- a) because the incandescent lamp supplies much more infra-red than the sun (proportionate to the same power in the visible spectrum), and
- b) because this infra-red is situated particularly in the region where it is mot strongly absorbed by the water vapour in the leaf'
- Due to the heating effect of infra-red radiation, it is possible that plant transpiration, which is a physical phenomenon of evaporation of water from the plant leaf surface, is favored by the fact that the molecules of water are capable of absorbing infra-red energy. The leaf subjected to infra-red radiation finds itself in exactly the same conditions as the substances exposed to drying in an oven' and one of the results must certainly be an evaporation of water or a transpiration in proportion to the illumination received or, more exactly, absorbed. It is rather

surprising that the opening of stomata, this is controlled completely by visible ray so increases the transpiration by only 14 per cent. The stomata open in visible rays, but they remain closed when the incident radiation comprises only infrared The L4 per cent increase in transpiration by the opening of stomata may be due probably to the facilitation of interchange of gases between the tissues of the plant and the atmosphere.

- In open-air cultivation in natural daylight, when the visible always accompanies the infra-red, the opening of the stomata coincides with the arrival of the whole range of radiation and the beginning of the phenomena of transpiration.
- It may be concluded that the preponderant action of infra-red radiation is to provide heat inside the leaf and thus to stimulate the evaporation of water in the process of transpiration. The question of whether transpiration is beneficial or harmful to plants cannot be easily answered, since it depend on the individual plant and the circumstance under which it is growing. It is well known that the quantity of water lost by plants in transpiration is very large. A plant may evaporate several hundred times of its weight in water.
- This might indicate a protective mechanism to the plant against heating since the evaporation process of these large amounts of water consumes a large proportion of the heating effect of the infrared portion of the light spectrum received by the plant. At the same time the transpiration process leads to the flow of water from the soil through the plant root, stem and leaves; and then again to the air in a continuous stream. This current of liquid is necessary for good growth of the plant. The abundance of infra-red radiation normally provokes intense transpiration. However, it becomes very harmful when the amount of water available to the plant is insufficient. The leaves become damaged and the plant withers (wilted).

The role of ultra-violet (U.V.) radiation:

- Wavelengths less than 390 nm are too short to be seen, but they are very active in certain chemical reactions. Plants do not require these wavelengths for normal growth and in general are not injuriously affected by them. Owing to the screening effect of ozone in the atmosphere they comprise about 2 o/o of radiation at the earth's surface
- Also, the epidermis of plants is essentially opaque (un-penetrable) to these rays. For these reasons ultraviolet radiation is not particularly important except to certain of the lower forms of plants.
- Ultra-violet tends to promote the formation of anthocyanins, is responsible in part for phototrophic phenomena, and by inactivating growth-promoting hormones, checks stem elongation.

The Role of Visible Light

- The most interesting characteristic of the effects of visible radiations is linked with their power of chemical activation. This activation is actually and excitation of the chemical molecule capable of absorbing light is a contribution of energy in quantities, which is proportional to the frequency of the luminaries vibration (Wave length).

- The quantum, or photon, transports an increasing amount of energy as we go from the infra-red towards the ultra-violet, passing through the visible. In the infrared the quanta are individually weak but numerous; they make the molecules vibrate without chemically activating them, heat them up and evoke the evaporation of water. In the visible, the heating up and the evaporation are produced in the same way, but in addition the quanta are capable of chemical actions, which become extremely important. The visible radiations are unique in being absolutely indispensable to plant life. In the ultraviolet, we should expect an increase in the chemical activity of photons of more and more concentrated energy, but the plant seems to defend itself from this action by them with an opaque epidermis. In the extreme ultra violet (W.L. shorter than 28.9 ,nm) ![e chemical activity becomes so great that the photons destroy the molecules of the epidermal cells and cause injury to plant. The part played by visible light, of wavelengths between 400 nm and 750 nm is certainly more complex than that of all the other radiations.

Light affects a number of plant functions:

1- Photosynthesis:

- The basic pattern of the plant shoot is directed toward efficiency in photosynthesis. The stem of the plant functions as a support enabling leaves to be exposed advantageously to light, and the large surface of the thin photosynthetic organs favors the absorption of light energy. The structure of the spongy mesophyll and the stomatal apparatus allows rapid gas exchange.
- Even the fact the photosynthesis utilizes the visible wavelengths of radiation most heavily is significant, for this is the region of the spectrum with the greatest energy values' Despite this apparent efficiency, full use is never taken of all the light energy, and under full insulation (radiation) there is a tremendous excess of unused light' On the average actively growing land plants use only about 1olo of visible radiation in photosynthesis. Respiration is a never-ending process in every protoplast, by which carbon compounds are oxidized to liberate energy for the maintenance of the plant's vital activity. whenever a plant is not carrying on photosynthesis its dry weight progressively decreases as a result of respiration. The amount of light required for photosynthesis to equal the respiratory use of carbon compounds, i.e. for coz to be neither absorbed nor evolved, is called the "compensation point". This value is always higher than the absolute minimum for photosynthesis, varying from about t 27 to 4,200 L in higher plants.-With tree seedlings the value usually lies between 2 and 30% of full sunlight. During long cloudy weather photosynthesis may lag behind respiration needs and food reserves decline.
- Growth obviously demands synthesis in excess of respiration, so that the Minimum requirements for this function are met only when light intensity exceeds

or has exceeded the compensation point. For example, the compensation point for seedlings of ***Pinus strobus*** is 1.,830 L, but twice this amount of energy is required to maintain growth. With equal energy, the monochromatic radiations of the visible spectrum are not equally effective for photosynthesis. It is already known that the orange yellow and the red have the maximum efficacy. This region of the spectrum, near 650 nm coincides with an absorption band of Chlorophyll. More recent. research has revealed a second, but lower, maximum of efficacy in the blue, in the neighborhood of 430 nm or 440 nm. In this region there is also an absorption band of chlorophyll. Between these two maxima, the efficacy of the monochromatic radiations is a little less, but is still considerable.

2- Phototropism:

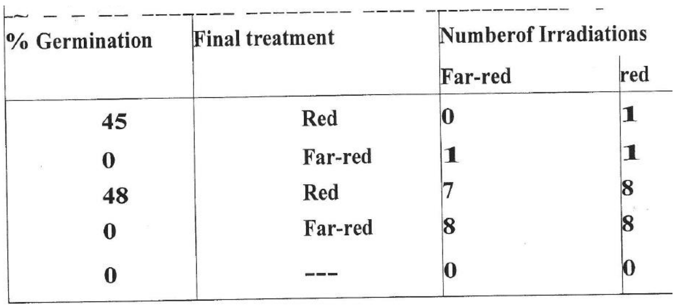
- Everyone has noticed that an indoor plant placed near a window grows towards the light and that it has to be turned everyday to keep the growth symmetrical. A simple experiment can be made with oats sown in a box receiving the daylight laterally. The seedlings shoot easily and instead of growing vertically are all inclined towards the direction from which the light comes. Light therefore has a considerable influence on the growth of plant cells.
- These facts may be compared with the great difference in appearance between plant seedlings (for example, potato shoots) kept in the light and those kept in the dark; In the light, they remain short and coloured, in the dark, they stretch out into thin stems and have the characteristics known as "***etiolation***", although there is no lack of nutritive substance in the soils (in case of potato, the tuber from which the seedlings grows is full of nutrients). But among the many phenomena distinguishable in etiolation we are concerned here only with the rapid growth in darkness. When a plant is illuminated on one side only, this side grows less quickly than the other which is in the shade, hence a curvature is produced which directs the tip of the stem towards the light. This influence of light on the inclination of the tip of the stem is called **“Phototropism"**.
- Owing to phototropism, plant stems are directed from regions with less illumination toward those with more. Thus, parts of the same plant, like the branches of a tree, or different plants in a group, like the blades in a field of corn do not group themselves together in the same place, but, on the contrary space themselves out with a certain regularity to make the best use of tight. Phototropism is therefore a very important factor in agriculture.
- Phototropism is initiated by certain wave lengths of light and not by the whole spectrum of visible light. We already know that white daylight is a mixture of radiations of different wavelengths. Have all those monochromatic radiations the same influence on growth?
- Thuson's experiments in 1934 showed that the blue and the violet of the spectrum are the only radiations really effective for phototropism In his experiments, he illuminated a young "oat" plant on one side with green spectral light and on the

other with blue spectral light. When the plant inclined towards the source of blue light he concluded that the blue has a greater retardate influence than the green.

- What is the process of this particular action of blue light? Light can only cause the activation of certain chemical molecules which absorb a light quantum. These activated molecules then become capable of entering into certain reactions which otherwise would be impossible for them, so that light may have the effect, either of starting a chain of new chemical transformations, or of transforming the sequence of reactions at one of its stages and modifying the result. An action similar to that of phototropism is produced by a substance' or a class of substances, called ***auxin***, which behaves like a growth hormone. It is present in the coleoptiles of young oats, principally at the tip. If the tip is cut off and placed on a piece of gelatin, the gelatin collects a small quantity of auxin, as is shown by experiment. The piece of gelatin is placed on the side of an oat stem from which the upper part of the coleoptiles has been removed. The growth of the stem then becomes asymmetrical; it grows more on the side which has received the gelatin and bends. With this substance' therefore, the reverse effect of the relative action of light is obtained. Apparently' light checks (stops) either the production, or the transport, or the activity, of auxin.

3- Germination:

- The seeds of most plants become sensitive to light When wetted. In certain instances germination is benefited; in others, it is retarded. ***Verbascum***, ***Lactuca*** sativa will not germinate without light stimulation, and ***Daucus carota***, ***Rumex***, and ***Picea abies*** germinate better with exposure to light. In contrast' plants such as ***Vanilla***, many Liliaceae, and ***Primula*** require darkness" ***Bromus tectorum*** and ***ulmus***, and many cacurbitaceae germinate better in darkness. The amount of light needed for stimulation of bluegrass (Poe) is considerable, but for tobacco even 0.01- second exposure allows more germination. Seeds requiring light obviously must, not be completely covered with soil when planted, but it has been found that, if seeds are soaked, given adequate light treatment, then dried again, light stimulation is retained and germination will take place even if the seeds are completely covered with soil.
- Recently, it became known that red light promotes germination whereas far red (Infra-red light) prevents it. For example l when moist seeds of the plant known as peppergrass (***Lepidium***) are exposed to red light before being planted in the dark, they germinate, but if they are exposed to far red, they do not'



% Germination	Final treatment	Numberof Irradiations	
		Far-red	red
45	Red	0	1
0	Far-red	1	1
48	Red	7	8
0	Far-red	8	8
0	---	0	0

- Effect of red and far-red light on the germination of seeds of ***Lepidium virginicum***. When both red and far-red are present at the same time they do not germinate. If they are exposed eight or more times to red and far-red light alternately, they will respond according to the irradiation they last received. It was red; they germinate; if it was far red they do not.

4- Photoperiodism:

- This term means the effect of the daily period of light on illumination. Light, which is the principal nourishment of green plants must: (1) be given to them in sufficient quality and not in excess. (2) It must be of suitable composition, without injurious ultraviolet and without too much infra-red. Natural daylight is in general well adapted to them. There remains a third factor which is extremely important. (3)The length of the day and night.
- The same quantity of light may be offered each day in a number of different ways. either by strong illuminations for a few hours followed by a long night, or by lower illuminations spread over a longer "period" and followed by a short night. The development of the same plant under these varying conditions may be profoundly different. With a certain period of daylight, a plant may be incapable of producing either buds or flowers or fruit; one species of onion will not form a bulb; another tuberous plant will remain without a tuber; a tree may remain in leaf until the winter and may be kilted by the frost, while the same plants, supplied with the same quantity of light, on the same ground and at the same temperature, but with suitable periods of daylight and darkness, will flower, produce seeds, bulbs and tubers and resist the winter frost. These curious consequences of day length, which were called "***photoperodism***" by the two Americans, Garner and Allard (1920)' are of considerable economic importance. For example, a species adapted to the long summer days of northern climates may be incapable of developing at lower latitude, even if the temperature is the same, because the summer days are shorter.
- ***Chrysanthemums*** may be made to. flower earlier or later, by artificial lengthening of the day with electric light, or, by shortening it with opaque material covering the plants' photoperiodism is still rather mysterious. It is strange, for example, that a very low illumination, of 5 to 10 Lux, 10000 times lower than the maximum illumination from the sun-given at night fall for a few hours to lengthen the day, is sufficient to produce a fundamental, change in the development of the plant. It

cannot be said that chemical substances elaborated by the plant, necessitating a luminous activation .for their synthesis, will be produced in sufficient quantify only after a rather long period of day light, for them the quantity of light would be important and not its duration.

- Perhaps certain slow syntheses are possible only when the action of light is sufficiently prolonged, perhaps others go beyond the stage of their accomplishment to give other combinations if darkness comes later. Although a number of species are evidently not sensitive to this factor, the length of day determines .for, the majority whether the plants will produce flowers or remain vegetative indefinitely. Long day plants flower only under day lengths longer than fourteen hours. plants in their response to the length of day are categorized into 4 groups:

1- Long-day plants:

- Some plants require long days for successful flowering and fruiting, although they make a vigorous vegetative growth during short days. There is a marked tendency for plants of temperate climates to flower and fruit at only certain periods of the year' some plants, e.g. violet, blossom early in spring. others such as ***Iris*** and **Poppy** begin to bloom at the start of summer, whereas ***Dahlia*** and ***Chrysanthemums*** are characteristic of fall (autumn). These differences in time of reproduction are not related to temperature but to the daily duration of light and darkness. Typical examples are the radish' iris, red clover, small cereals and spinach. These flowers regularly during the long days of late spring and early summer. All may be brought into blossom and fruitage in midwinter, however, if artificial light is used to prolong the daily illumination period to 15 or 16 hours.

2- Short-day plants:

- short-day plants flowering is induced by short period, of less than 12 hours' Plants such as tobacco and ***Dahlia*** continue to develop only vegetatively under a long-day illumination. The blossom normally only when short days occur. This is true of a large group of plants including most late-blooming summer annuals.

3- Day-neutral Plants:

- These plants can form their flower buds under any period of illumination. They apparently have no critical length of day for reproduction and under suitable conditions for growth they tend to flower at ail seasons of the year. Example of this category of plants is the cultivated sunflower which is not influenced in time of flowering by length of the day.

4- Intermediate Plants:

- These plants flower at a day length of twelve to fourteen hours but are inhibited in reproduction by day lengths either above or below this duration' plants within the same group may also differ in their response to day length' subsequent to flower initiation. For example, the strawberry is a short day plant for floral initiation, but it is a long-day plant for fruit formation. Other short-day plants such as the soybean prefer a short photoperiod through.

- Later experiments, however, turned up a surprising fact' If a plant requires a certain length of the day to flower, darkening the plant for a part of the day did not interfere with its flowering on the other hand, illumination at night affected the plant's flowering. Thus the critical factor in photoperiodism is not the length of the day but the length of night; strictly speaking, plants should be classified as long-night and short-nigh rather than long day and short-day'

Photoperiodism as a factor in plant distribution:

- photoperiodism is an important factor in the natural distribution of plants' In general plants that have originated in low latitudes require short days for flowering' while those of high latitudes are long-day plants when the latter are moved to low latitudes, they will not produce blossoms when low-latitude plants are grown in the long photoperiod of high latitudes they will continue to grow vegetatively until killed by frost. some wild varieties of sugar-cane flower only in the tropics' spinach, on the other hand; never flowers in the tropics, because it requires fourteen hours of daylight for at least two weeks. Maize is a short day plant that has difficulty in adapting to the long photoperiods.

Practical significance of photoperiodism:

- Among field and garden crops, some plants are grown for their vegetative parts alone, others for their fruit or seeds, and in still others maximum yields of both vegetative and reproductive parts are desired' Two or more weeks in time of planting may definitely determine whether the plant activities will be directed toward the purely vegetative or the reproductive from of development. These facts strongly emphasize the importance of accurately knowing the correct time for planting each crop in order to secure the highest yield. Even different varieties and strains of the same species differ markedly as to the particular length of day most favorable for flowering or for vegetative development' Failure of acclimatization of many species believed due to unfavorable temperature may actually have resulted from an unsuitable length of day. **Radisheso** for example, do not blossom in the tropics and the biennial beets of temperate regions become annuals in Alaska' Knowledge of photoperiodism, as these responses to length of day are called Should aid the plant breeder to secure for any particular region earlier or later varieties, more fruitful or larger growing forms. The problem of extending the northern or southern range of crop plants is also more clearly defined' In middle and high latitudes, certain long-day plants will not flower in due time when they are most needed If they are exposed to artificial illumination for a proper length of time' the flowering date can be specified. This is used in Netherland, where artificial light is used to hasten the blooming of tulip and to retard the sprouting of seed potatoes. In the field of breeding, flower initiation has greatly reduced the time span from germination to maturity. New varieties can be developed more rapidly. The artificial flower induction also makes it possible to cross plants that flower at different seasons in natural conditions.

Effect of light on plant structure:

- All green plants require tight, although bacteria and fungi may flourish even in dark caves and in the depths of oceans. In fact many species of saprophytic plants are kiiled by exposure to light, a fact well known in sanitation. Many saprophl'tic and parasitic fungi that can grow vegetatively in the dark require light for reproduction' Exposure of bacteria to direct sunlight kills the cells. Lethal effect is due chiefly to the ultraviolet rays between 254 and280 nm although violet and blue light have some effect. The same wavelengths have an inhibitory effect upon fungi' when disease producing, fungi are more sensitive to ultraviolet than their hosts, irradiation can be used in controlling them.
- Light influences the whole course of higher development of the plant, exerting a profound effect upon its characteristic form and structure. It affects plants in many ways. Through its action chlorophyll and many other pigments, growth substances or hormones as well carbohydrates are synthesized. Light influences the position of the chloroplasts, the opening and closing of stomata, and has a profound effect upon transpiration.
- Light is necessary for the production of chlorophyll. A primary response of the plant to light is the formation of chlorophyll. This response does not occur in plants such as bacteria and fungi. Plants with plastids produce chlorophyll only in light' and the chlorophyll practically always disappear in continued darkness; chlorophyll cannot function in synthesis of carbohydrates without light.
- Light influences the position and number of chloroplasts in the leaf. In the upper part of the leaf which receives full sunshine, and where chloroplasts are much more abundant, they are arranged in line with direction of light and thus screen each other from the full effect of the radiant energy. It has been shown that a single layer of chloroplasts absorbs about 30% of the light falling upon it. Absorption in the second layer is reduced to 2loh, in the third to 15%, and in the fourth to l0% but deeper layers of the chloroplasts absorb very little' In the shade, there is a need to obtain all the light possible. Accordingly' the plastids, which are fewer in number, are arranged at right angles to the light rays' thus increasing the surface for absorption. Shade results in thin leaves often with a single layer of palisade cells and loosely arranged **chlorenchyma**. A variety of plants growing under low light intensities (in forests or shaded places) develop only are layer of palisade tissues those under strong light intensities (in desert or exposed places) had two or more distinct layers.
- Thickness of the leaf increased with increasing light intensify. The sponge cells elongate more or less parallel to the surface, thus increasing the light absorbing surface. Palisade tissue is found in nearly all leaves where the light is diffuse. The cells that normally form palisade in the sun develop into sponge cells in the shade. Conversely, sponge cells under strong illumination develop into palisade' In places where the under (lower) surface of the leaf is also highly illuminated, for example by the reflection of light from white sand, palisade also develops in the lower part

- The total absence of light results in greatly attenuated, weak stems with tissues weakly differentiated and little mechanical tissue. There are few or no branches and the leaves fait to expand. The root system is poorly developed. The plant is pale yellow or whitish in colour, due to the lack of chlorophyll and is said to be "etiolated". while diffuse light promotes the development of vegetative structures, intense light favors the development of flowers, fruits, and seeds. under extreme sunlight intensities, transpiration becomes excessive. Structural changes occur which protect the plant from excessive heating and desiccation. The vegetation is often characterized by plants with low stature and small leaves of considerable thickness.
- Rapid transpiration is promoted by an increase in water-conducting tissue. Many crops grown for their vegetative parts, such as potatoes, carrots, turnips, and garden peat's, yield best where there is a high percentage of cloudy days. Conversely, the greatest grain-producing areas are in regions where there is a high percentage of bright sunny days. Fruit is likewise produced in great quantities where the light intensity is reduced only slightly by clouds or atmospheric moisture during the entire growing season. The yield of cotton is greatly reduced during unusually cloudy days in the growing season, although the plants make an excessive vegetative growth.

Effect of light on transpiration:

- The detrimental effects of high light intensities include their influence in promoting rapid, transpiration. Light stimulates the guard cells to open' as well as increases the permeability of the plasma membranes. The stomata of all plants remain open all day and close at night. Transpiration increases rapidly at daybreak and slows to a very low level at sundown, if not earlier, owing to a tissue developing water deficit. Although algae may use as much as25% of CO_2 supply, water deficit, etc. Of the remainder approximately one third is reflected back from the leaf or is transmitted through it, and about 2/3 is absorbed, changed into heat energy' then lost by radiation or used up in the vaporization of water. Since some of the light rays that penetrate tissues are always changed into long heat rays, it is apparent that light effects can never be completely separated from heat effects, and because heat influences transpiration and other physiologic processes, the investigation of light as an ecologic factor is very complicated.

Modifications of the effect of light by temperature and other factors:

- Temperature and light influences are inextricably related in their influence on plants. Suitable intensities in one compensate in part for deficiencies in the other. For example, photoperiodism can be altered somewhat by the intensity or quality of light' and it can be reversed by the manipulation of temperature. Thus, verbalization allows winter wheat to flower during long photoperiods, whereas without temperature stimulation these varieties are distinctly short-day plants. Also, if moistened grains of sorghum and millet are kept in darkness for 5 to 10 days at temperatures between 27 and 29°C, the need for short photoperiods of the plants produced is removed. Soil fertility is also known to effect light relations. The less fertile the soil' the lower the chlorophyll content of the leaves and the less their photosynthetic efficiency under a given amount of light. There are, however, definite limits to the extent to which fertility can compensate for inadequate light energy.

III.WATER

Importance of water to Plants:

- In the physiology of plants water is of extreme importance in many ways:

1. Being a universal solvent, dissolves all minerals in the soil. It is the medium by which solutes enter into the plant & move about through the tissues.
2. It is a raw material in photosynthesis.
3. It is essential in maintaining the turgidity without which the cells cannot function actively. It is important for the activity of the protoplasm. Very few tissues are able to survive if their water content is reduced to about l0%.
4. Acts as a thermal regulator in the plant tissues. This is due to its high heat capacity' being capable of absorbing large amounts of heat with relatively little change in temperature.

- The water in the soil is continuous with that in plant, and the entire system is constant upward movement since the shoot loses water to the atmosphere at almost all times. Nearly all this water moving upward in the plant is lost in transpiration.
- Only about 0.1 - 0.3% of it being tied up in chemical compounds. The intake of water by plant roots from the soil and its loss to the atmosphere are strongly controlled by the factors of the environment.

Atmospheric moisture

- The water in the atmosphere which supplies the soil, and consequently the plant, takes different forms:

1- Invisible vapor (Humidity):

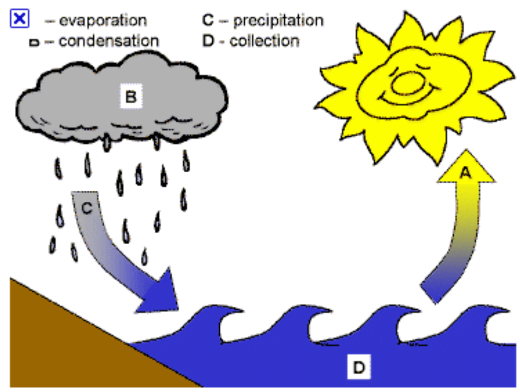
- The invisible water vapour in the air is referred to as "***humidity***".
- Its amount in the air depends to a great extent on air temperature. Warm air can hold more water vapour than cold air.The capacity of air for holding water vapour doubles with each increase of 20°F (11.1°C) in temperature.
- The amount of water vapour held by air at a given temperature is called its ***"absolute humidity"***.
- Air humidity is usually expressed as "***relative humidity***" which is an expression of the air humidity as a percentage of the maximum amount it can hold at a given temperature.
- ***Dew point*** : It follows that, when a body of moist, warm air is cooled, the relative humidity approaches 100% (even though the actual water-vapour content of the air

remains constant), and if further cooling takes place, the "***dew point***" is reached and the excess vapour is condensed into droplets of liquid.

- Thus, a cubic meter of saturated air (R.H. = 100%) at 80^{o}F, when cooled down to 60^{o}F, will lose by condensation half its water content as visible droplets. At the changed temperature, with only half its former absolute humidity, the relative humidity is still 100%.

Vapour Pressure

- Relative humidity normally undergoes a daily rhythm, changing from low during the day to high at night when the air cools'
- Since the relative humidity of the air is changed by temperature, the effect of atmospheric humidity on plants will be always inseparable from temperature effect. For this reason, atmospheric humidity is better expressed as the "***vapour pressure***".
- This expression is a statement of the activity of water vapour in the air under the influence of temperature. More significant to the plant is the difference between the water vapour pressure inside the leaf tissues, always assumed to be near saturation (exactly the relative humidity inside the tissue is 99.8%) and that of the air adjacent to the leaf. This is called the "vapour saturation deficit" of the air.
- ***2- Visible vapour: (Cloud and fog):***
- Cloud and fog consist of water droplets, or sometimes minute ice crystals which result from the cooling of air to a temperature below its dew point. They differ only in location. The first forms at high altitudes above ground and the latter in the air layers near the ground surface.
- When further, cooled both cloud and fog condense into particles or droplets large enough to precipitate out of the atmosphere. On the other hand, should clouds be forced downward to warmer levels of the atmosphere, or foggy air be warmed up, the visible vapour evaporates into the invisible from after which the relative humidity begins to drop.
- Water vapour in the atmosphere intercepts much of the solar radiation energy before it reaches the earth's surface. With all other factors remaining constant, an increase in atmospheric humidity reduces the rates of evaporation and transpiration because the vapour-pressure gradient between the atmosphere and moist surfaces is lowered .
- Moisture precipitation from cooled fogs may be absorbed directly by plants. In some rainless coastal areas, e.g. the coast of **Peru in the western part of South America**, it serves as the sole source of water for plants.



- In less arid regions the water is deposited conspicuously in the form of drops on the leaves in large amounts. Sometimes this amount of water condensed is so great that it falls to the ground, materially increasing the supply of soil moisture. When this takes place, its effect on the distribution of annual and low plants.
- Some plants are capable of absorbing atmospheric moisture directly from the atmosphere. For example desiccated dry mosses and lichens absorb moisture from a humid without preliminary condensation. In general the abundance of these plants is in direct proportion to the humidity of the climate.
- some desert plants can take up water directly from the air when the relative humidity rises above 85%.
-

3- Dew

- Whenever loss of heat by radiation cools a surface below the dew point, water vapour from the air will condense on it as a film of dew, even if relative humidity at a height of l.2 m is no more than 60%. Turbulent air prevents the required temperature gradient, but gentle air currents thicken dew films by bringing fresh supplies of air into contact with the surfaces.
- Such dew forming in leaves may be absorbed through the cuticle of normal epidermal cell, or through specialized cells. Shallow-rooted desert annuals may depend more upon dew condensed on the soil than upon rain. Larger desert plants have been found to suffer a marked reduction in growth when covered at night. At the very least, dew shortens the diurnal period of transpiration, and thus conserves soil water.
-

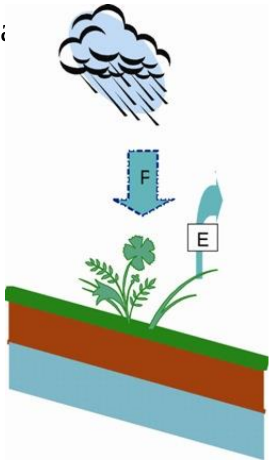
4- Precipitation:

- There is always sufficient water vapour in the air to be precipitated in different forms, but the proper meteorological conditions to cause this precipitation is frequency absent. precipitation of atmospheric moisture takes different forms, according to the prevailing climatic factors according to the prevailing climatic factors prevailing at or before the times of occurrence of precipitation:

1. **Rain**: Although rain is of tremendous importance to plants as a source of moisture, in general it is of little direct importance.
2. **Snow**: precipitation of atmospheric moisture in the form of snow caused damage (mechanical) to the plants as a result of its heavy weight resulting on accumulation on plants.

- Very often large trees are bent prostrate or their branches are broken off. In areas of rough topography, snow accumulation on slopes facing the north affects the distribution of plants and the types of plants on the slopes. Deep snow cover may press seedlings down to the ground so as to favor their parasitism by fungi which are active at the ground surface' Snow when melts at times and to the supply of soil water.

- ***Precipitation Effectiveness: -***
- Although all soil moisture is derived from precipitation, not all precipitation is equally effective in increasing soil moisture.
  - The slower and more gentle the showers the higher the percenta soaks into the soil in relation to that lost as runoff.

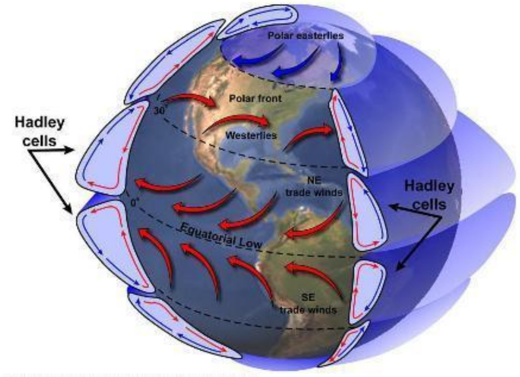


- 2. The greater the quantity of water falling during anyone rainy period, the more of it sinks below the reach of direct surface desiccation.
- Thus, in dry-climates a number of showers to falling up to several inches of rain in summer may have no effect in raising the soil moisture content because the individual rains are too light and too widely separated for successive increments to have cumulative effect' The longer and more severe the drought greater the quantity of rain fall that will be required subsequently to break it.
- The affectivity of precipitation as a source of soil moisture for plants is best measured by direct studies of the degree of penetration and duration of moisture in the soil. Efforts have been made to fined direct means of evaluating this factor by utilizing climatological data. This is based on the fact that the severity of the evaporative conditions after a rainfall affects the duration of favorably moist conditions. The more cool and humid the climate, the more effective a given amount of rain fall.
- A simple equation to determine the precipitation effectiveness is:

Pp.n. effectiveness = number of rainy days x P (mm)/T(ºC) + 10

- where P is the mean amount of rainfall and T the mean temperature.

IV. Wind



- Air moves from a region of high pressure to one of low pressure and the differences in pressure are largely the result of unequal heating of the atmosphere.
- The equatorial regions receive more heat than regions to north or south; consequently, low pressures normally exist in the lower latitudes.
- The tendency then, is for air to move the poles toward the Equator, there to rise and return toward the poles. This pattern, although true in general, is modified by the deflecting action of the earth’s rotation and by differences in

  temperature resulting from oceans and land masses.

  - Continents in temperate zones tend to become very hot in summer and the resulting low pressure produce winds that blow inland. The cold of winter reverses the pressure, and winds tend to out blowing. In mountain areas or along sea coasts these seasonal trends may have daily variations again produced by temperature differences.
  - Mountain valley and slopes, which are often warmed rapidly during the day, produce valley breezes blowing upward. At night, the rapid cooling of bare high ridges results in a flow of cold air down the alleys. The contrast between day and night temperatures of land and water results in an offshore breeze at night as the land cools rapidly and higher pressures result.

- During the days, the land again heats up rapidly above the temperature of the sea, and an inshore breeze develops that may be noticeable for several miles inland. This brief outline of factors producing wind, although greatly over-simplified, should serve to indicate that air is almost constantly in motion. This should also indicate that, within limits, the general plan of motion is predicable for seasons and parts of the earthThe rate of movement of air is generally expressed as average velocity over an interval of time, such as **meters/ second or kilometers/ hour**. The velocity of wind is affected by the topography, vegetation masses, by position with respect to the sea shore, and by major paths of wind movement. So the rate of air movement increases regularly with increasing height above the ground.
- It is necessary to distinguish between wind in the free atmosphere and the surface wind as measured 10 m above the ground. The former is dominated by the distribution of atmospheric pressure, while the surface wind is influenced partly by the landscape on a scale up to or beyond several Kms. Below 10 m the wind speed is influenced by smaller scales of roughness consisting of the plants themselves' Within the vegetation, the air flow is much retarded by plant parts, and approaches zero near surfaces. The wind over vegetation is also influenced by local wind systems which include thermal circulations produced by a differential heating and cooling of adjacent land areas and winds influenced by topographic factors, such as the narrowing of valleys.

Effects of wind on Plants.

1-Desiccationالتجفيف:

- In still air evaporation of water from a wet surface, such as moist soil on a turgid leaf with open stomata's, is simply a process of diffusion. When air is in motion the process becomes strongly affected by **convection**. Wind causes evaporation even when the **saturation deficit** (gradient in water vapour concentration between **leaf surface** or moist soil and **air above**) is **zero**.
- Wind increases transpiration by moving layers of humid air which tend to accumulate adjacent to the plant surfaces. This action is especially facilitated by small-sized leaf blades. Wind also bends leaves, causing alternate expansion and contraction of the

intercellular space, which forces saturated air out and drier air in. At high wind velocity, the leaf tissues may therefore lose turgidity and the stomates are then forced to close. Transpiration then will take place through the cuticle, and the amount of water lost will depend largely on the thickness of the cuticle.

- **2- Dwarfing:**
- Plants developing under the influence of frequent dry winds never attain a degree of hydration, and consequently of turgidity, that enables them to expand their maturing cells to normal size. As a result of this, all organs are dwarfed because constituent cells become fixed at a small (subnormal) size.

  Although dwarfing involves low dry-matter production, yet the total water utilization is not reduced in proportion, so that the transpiration efficiency is reduced' In addition, the date of maturity is advanced in some plants, and the number of secondary branches may be increased.

3- Deformation (wind-training):

- When developing shoots are subjected to strong wind pressure from a constant direction, the form and position of the shoot may become permanently altered. Deformation, when caused by moist winds, is not accompanied by dwarfing. In some instances, the side of the plant opposite to the direction of the prevailing winds (the windward side) is so desiccated that new growth is killed before it is well established.
- Lateral buds taking over the growth may or may not survive, and a scrubby matted growth develops on the windward side. To the reward (the other side similar to the direction of wind) the new shoots are protected by the trunk and the other parts of the plant, and growth continues on there.

- This result, over a period of years' in a symmetric growth forms known as '**flagging growth**' in which only the Leeward side of the plant carries normal growth. Some branches may grow completely around the trunk from the windward to the leeward side. Such type of growth is commonly found in exposed places at high altitudes in mountain areas. In these areas' plants which normally grow upright may become prostrate and form mats fitting into hollows or behind protecting rocks.
- Sometimes deformation occurs in trees that have regular seasonal active secondary thickening. secondary thickening on the windward side of these trees is suppressed to the extent that their trunks become no more of the normal cylindrical form. In cross section, the trunks take deformed **oval** shapes as a result of asymmetric secondary growth where the growth is far greater on the leeward side of the trunks than on the windward side.

4- Anatomical modifications:

- When a tree trunk becomes bent as a result of wind deformation' a dense reddish type of xylem called "**compression wood**" forms on the compressed side and this helps further bending in the same direction. In herbaceous plants wind blowing may stimulate the formation of more **collenchymas** than usually found in protected plants.

5- Lodging:

- This is a type of damage, cause by strong winds, to herbaceous plants and grasses such as wheat, maize and sugar cane. wind blowing will cause the fall down of the fleshy shoots and these tend to take a prostrate type of growth
- In case of crop plants, such as wheat, maize and barley, it may greatly reduce the yield since it affects conduction of water to the plant tops because of the mechanical damage caused to the stem tissue. It may also cause the damage of the developing inflorescences and seeds since they become located near the soil which is frequently wet.
- **6- Uprooting:**
- Trees may be uprooted even if the stems successfully resist breakage by high winds. uprooting is helped by the high moisture content (saturated soil) resulting from rainfall which usually accompany strong wind storms especially in tropical and subtropical areas.

7- Abrasions:

- When wind carries particles of ice or soil (such as the **Khamaseen** winds in Egypt); or winds blowing on coastal areas of seas and oceans cause severe abrasive damage to the soft parts of the plants. Buds may be eroded away from the windward sides of woody stems. crops growing in sandy soils are frequently damaged in windy climates.

8- Effect of soil erosion and deposition:

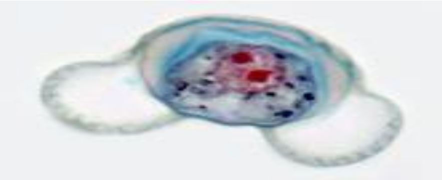
- The slightest air movement shifts dust particles from place to place, and increasing velocity results in the transport of larger particles of soil in increasing amount wind effect in this respect is noticeable in dry climates where there is a prevailing wind and a minimum of plant cover.
- Sand beaches and vast desert regions (such as the western desert in Egypt) are dry; free of vegetation, and swept by prevailing winds, which carry the soil along near the earth's surface. Any obstacle than slows down the velocity of wind causes some of its load to deposit and starts a mound or ridge called "**dune**"
- Some dunes grow, by further deposition of more sand, to a height of several hundred feet. A well developed dune attains a crescent-shape having a gentle slope on the windward direction and a sharp drop on the leeward direction' A dune is never completely stable (or fixed) unless it becomes covered with dense growth of plants.
- It always moves in the direction of prevailing winds, sometimes covering roads railways or villages in its path. This creates great problems in desert areas. In Egypt, places such as the Kharga and Dakhla oases (The New Valley Province) suffer greatly from moving sand dunes wind breaks, established by growing kinds of trees (Casuarinas-type) at close distances are effective in protecting cultivations to some

extent. Wind may also cause the soil to lose its surface layer which is usually more fertile.

- **9- Transportation by Wind:**
- Wind is an efficient agent in dissemination upon which most terrestrial plants depend to scatter their disseminules الاعضاء المتنقلة . In such cases the disseminules, which are either seeds or whole fruits, have adaptive characteristics which enable them to be carried by wind. This helps the plants to invade new areas in which they did not grow before.
- In addition, pollination in a large number of plants is carried out only by means of wind (**anemophily الهجرة بالرياح**). The pollen of grasses, willow and pine are carried in large number of distances exceeding l000 kms.
- Animophilous plants have, therefore, developed certain morphologic adaptations that facilitate wind pollination of these adaptations are the (1) long stamens extruding from the perianth and the well exposed, (2) feathery stigmas which catch pollen carried by wind.
- The flowers are typically <u>unisexual</u>. In certain plants, e.g. the gymnosperms' such as ***Pinus***, the pollen grain has a pair of wings which helps it to be buoyant in air.

Morphological adaptations in plant disseminules carried by wind are the following:

1- Minute seeds:



Of this type are seeds of plants belonging to families **Orchidaceae** and **orobanchaceae**, the seed weight less than 0.0002 milligram.

2- Feathery disseminules:

Such as the seeds of plants belonging to the families Salicaceae and Composite. The seed carries a large number of minute hairs which help its buoyancy in air.

3- Winged disseminules:

Seeds and fruits of many forest trees possess wings that enable them to be carried away from the trees they are produced.

4- Saccate disseminules:

Seeds of some plants belonging to family Chenopodiaceae are enclosed in inflated papery structures which can be rolled over the ground by wind.

5- Tumbling disseminules:

Whole inflorescences, and sometimes whole shoots, of some desert plants are cut off from the plant and are rolled on the ground surface by wind action' During rolling, the seeds are scattered in a large area in the path of rolling.

6- Ejaculated disseminules:

The fruits of some plants when open are able to throw the seeds to a distance way from the plant. Plants that have fruits of this type are ***Iris***, ***Papaver*** and ***Delphinium***. This is, however, a weak mechanism of dissemination.

EDAPHIC FACTORS

- Edaphic factors are those due to the soil in which the plant is rooted, and it is usually easy to draw a line between these and climatic factors, though, the characters of the soil are largely dependent upon climate.
- For example, the soils of a desert are very different from those of a region of high rainfall distributed through the year' even if they are derived from identical rocks.
- The edaphic factors would be master factors, because they would differentiate the plant communities inhabiting the soils on the different types of rocks.

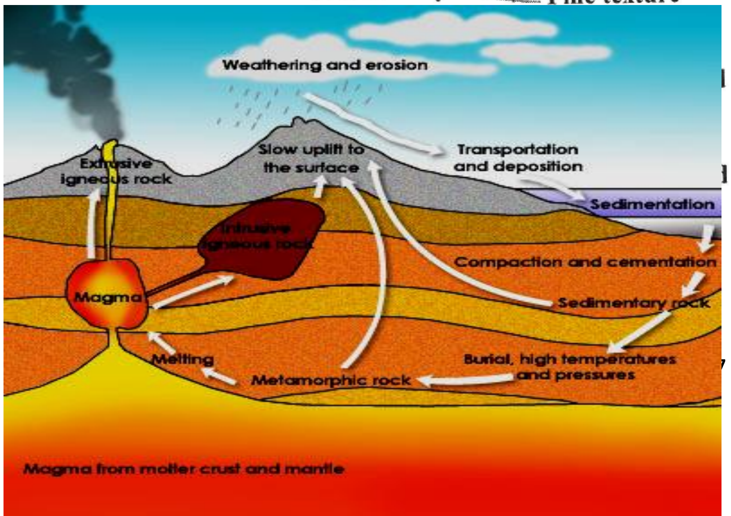
Soil

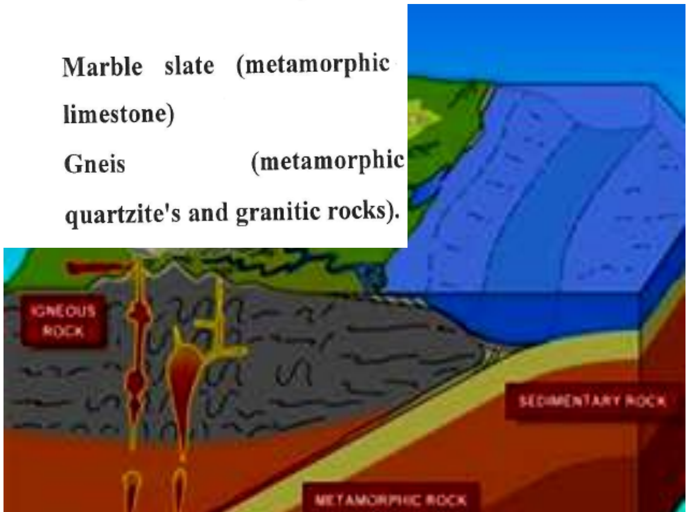
- The soil is the unconsolidated outer layer of the earth's crust, ranging in thickness from a mere film to some-what more than 10 feats, which through processes of weathering and the incorporation of organic matter has become adapted to the growth of plants. Nearly all higher plants except parasites and epiphytes are rooted in the soil.
- The soil often contain and acts upon a much more extensive portion of the plant body than does the atmosphere' Moreover, vegetation has played a remarkable role in the formation of this medium in which plants are anchored and form which they obtain their water and nutrients.
- ***Nature and origin of soil:***

  The geological formations through weathering produce the parent materials of soil. These materials constitute the bulk of the soil and for a long time determine its physical character. Thus the chief components of most soils are derived from rocks. The following table shows the soil-forming rocks and their composition:

  Rocky Example

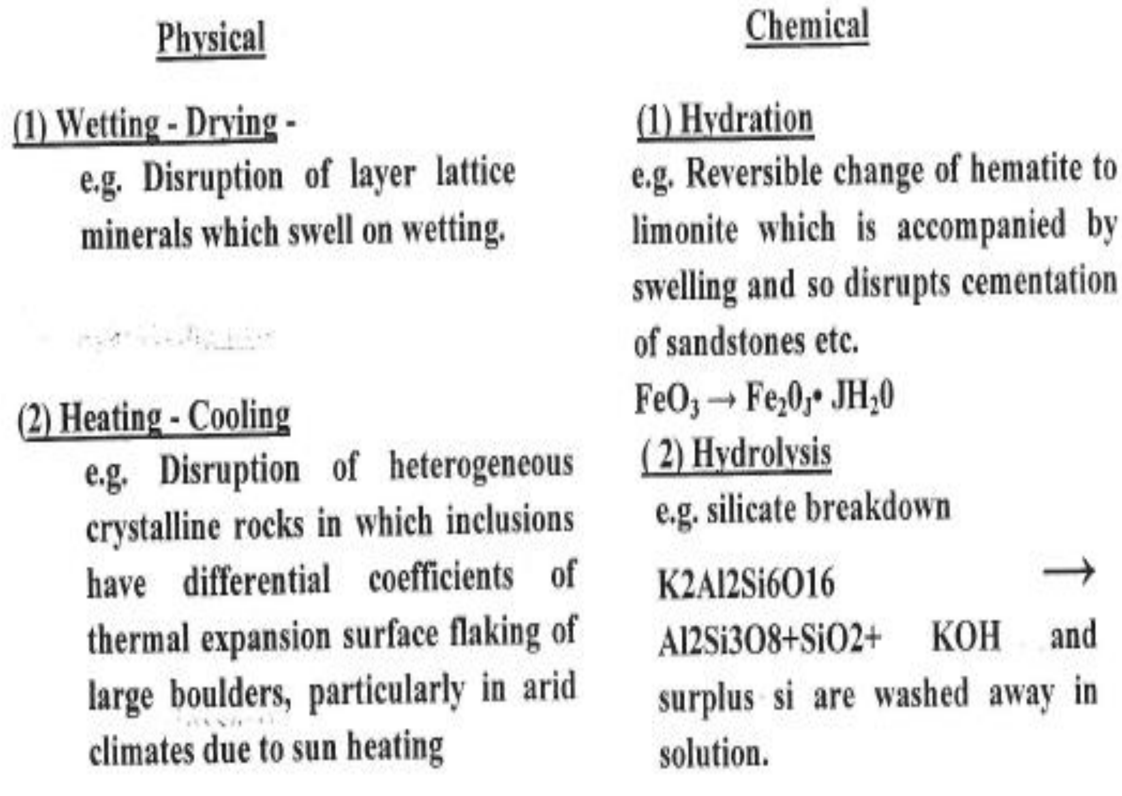
	Rock type	Example
Igneous	Quartz rich (acidic)	Granite
	Quartz poor (basic)	Basalt
Sedimentary	Coarse texture	Sandstone - sand
	Fine texture	Mudstone - shales-clays
		Marble slate (metamorphic limestone)
		Gneis (metamorphic quartzite's and granitic rocks).





The weathering processes:

Bare rock surfaces and developing soils are exposed to a range of physical, chemical and biological processes which lead to mechanical and chemical disruption of their components which we can summarized in the following table:



Physical	Chemical
(1) Wetting - Drying - e.g. Disruption of layer lattice minerals which swell on wetting.	(1) Hydration e.g. Reversible change of hematite to limonite which is accompanied by swelling and so disrupts cementation of sandstones etc. $FeO_3 \rightarrow Fe_20_J \cdot JH_20$
(2) Heating - Cooling e.g. Disruption of heterogeneous crystalline rocks in which inclusions have differential coefficients of thermal expansion surface flaking of large boulders, particularly in arid climates due to sun heating	(2) Hydrolysis e.g. silicate breakdown K2Al2Si6O16 → Al2Si3O8+SiO2+ KOH and surplus si are washed away in solution.

(3) Freezing

e.g. Disruption of porous, lamellar or vesicular rocks by frost shatter due to expansion of water during freezing.

(4) Glaciations

e.g· physical erosion by grinding process more soluble than the carbonate.

(5) Solution

Removal of more mobile component such as Ca, S04, Cl, etc.

(6) Sand blast

e.g.· erosion of upstanding rocks in arid desert condition.

(3) Oxidation-reduction e.g. $Fe+ \rightarrow Fe++$ causes disruption of cementation as Fe++ is much more soluble than Fe+++.

(4) Carbonation

e·g. $CaCO3 \rightarrow Ca(HCO_3)2$ leads to solution loss of $CaCo_3$ cemented rocks as the bicarbonate is

(5) Chelation

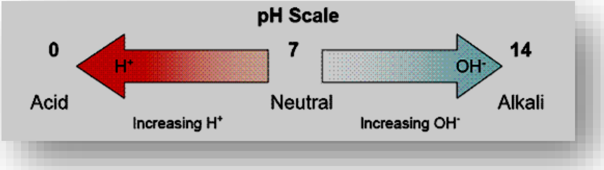
Essentially a consequence of biochemical activity, various metals being dissolved as chelates with organic products of plant and microorganism activity.

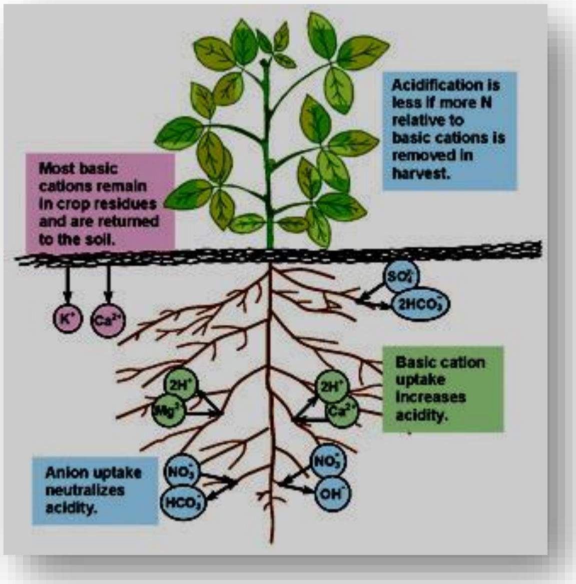
- Chemical and physical processes alone give rise to a biotic crusts of weathering products which are only the raw material of soil formation. Most rock surfaces do not remain free of life for very long and the physiochemical weathering processes are soon rein- forced by the often potent effects of numerous microorganisms.
- Lichens are able to extract nutrients which would be unavailable to higher plants. Retention of water by the thin layer of lichen, fungal and bacterial organisms on rock surfaces prolongs the period during which chemical processes can proceed colonization of a juvenile soil by higher plants adds yet another complication to the soil forming process, greatly increasing the energy fixing capacity of the surface and increasing the supply of decaying organic matter.
- Soluble organic compounds also diffuse into the rhizo-sphere zone from the roots and wash into the soil surface from leaf-drip. Deeper penetration of roots will tend to increase the depth range of cyclic processes involving nutrient elements, soluble elements leached downward being returned to the surface by transport through the plant. Rock weathering is therefore, for a short time a physiochemical process but rapidly becomes biogenic with a consequent increase in the overall rate.
- ***Pedogenesis***: a biological phenomenon by which crusts of weathered rock debris are converted to true soils comprising a complex mineral matrix in association with rang of organic compounds' very often carrying a rich microorganism population which is a reflection of the nature of the parent material and its interaction with climate, topography, plant cover and age.

Chemical characters:

- The basis of the great majority of soils is the collection of inorganic particles produced by disintegration (weathering), both physical and chemical' of the parent "**rock**" the hard rock's igneous or metamorphic, or sedimentary grits, sandstones or limestone or the softer **shales, clays and alluvia**.
- Besides these inorganic particles, an organic constituent (**humus**) is nearly always present. According to particular rock from which the soil is derived the nature of the soil particles is different, both chemically and physically, but the main in organic chemical substances forming the basis of soils are three: (**complex alumino-silicates, silica and calcium carbonate**).
- The **alumino-silicates** are ultimately derived from such rock-forming minerals as the felspars, hornblende, augite and mica of igneous rocks' which pass into the sedimentary rocks by erosion, transport and redeposit, generally through the agency of water. The **silica** comes largely from the quartz of acidic igneous rocks and form sandstones.
- **Calcium carbonate** comes mainly from limestones originally formed in bygone seas by such organisms as corals, and calcareous algae. with the alumino-silicates are associated various elements which form basic (alkaline) salts such as Ca^{+2}, Mg^{+2}, K^{+} and Na^{+} all except the last being essential elements in plant nutrition.
- **Iron** salts are practically always present (iron being an essential element in the formation of chlorophyll) and the oxidation from ferrous to ferric salts during weathering gives the brown or red colour of many soils.
- **Phosphorus and sulpher**, usually in the form of PO_4^{-3} and SO_4^{-2} or their acids, are always present and essential to plant life.
- **Nitrogen**, which is an essential constituent of plant proteins, is mainly derived from humus but also partly by fixation of the free nitrogen of the air.
- **Traces of other elements** such as Boron and manganese, which have recently been shown to play a vital part in most plant life, though in extremely minute quantities, are found in most soils, and others again are frequently absorbed by plants but probably do not affect their vital processes.
- The alumino-silicates form the center of the essential process of chemical weathering in soil.
- The originally very complex silicates are broken down, largely by hydrolysis; and the bases removed in solution, while a part of the silica is separated from the complex silicates.
- The residue is still essentially a complex alumino-silicate, which may vary considerably in chemical composition and physical properties, some of it forming the very fine particles of colloidal clay.
- This colloidal clay, together with the colloidal humus derived from the decomposition of dead vegetation and this clay humus complex is the main reactive part of the soil the i.e. part within which the main chemical processes occur.

- Calcium is the dominant basic ion in the soil and when present in quantity it imparts' physical and chemical stability to the whole weathering complex' aggregating the fine colloidal particles into compound particles and thus giving a granular or "crumb" structure to the very fine grained clays which without calcium, are unfavorable to many forms of life. While the calcium ions are thus the great stabilizing agent in soil, the free hydrogen ions, derived from the ionization of acids, promote chemical change. These are the active agents in the chemical action of acids and in soil are derived mainly from the carbonic acid dissolved in soil water, from the organic acids of humus, and from other acids produced as the result of chemical changes.
- <u>pH is defined as the negative logarithm of hydrogen ion activity where activity is understood to mean effective concentration.</u>
- Increasing acidity raises the H^+ ion concentration, lowers the OH^- ion concentration and lowers the pH value. Increasing alkalinity raises the OH^- ion concentration with a corresponding reduction in H^+ concentration and thus increases pH value.





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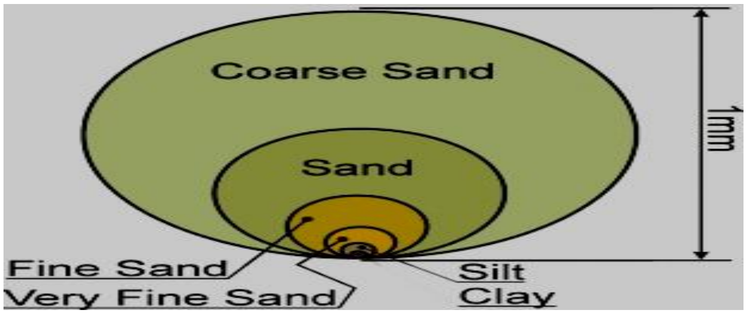
- Natural soils usually have pH values between about pH 3.0 and 8.4, the upper value being the $CaCO_3$ equilibrium with atmospheric CO_2 concentration and the lower value, the soil solution equilibrium with highly hydrogen-saturated soil. More extreme values do occur in un-usual soil types.
- Some alkali soils with high Na_2CO_3 content reach values of pH 10 - 10.5
- ***Physical characters of soils: Soil texture***
- The nature and size of the mineral particles constituting the inorganic frame work of soils not only influence the chemical, processes, but directly determine the physical nature of a soil and its effect upon plants.
- The texture of a soil depends primarily on the sizes of its mineral particles, and this feature is of great importance to plants because it controls aeration, water holding capacity and the ease with which water can traverse the soil.
- The proportion of particles of different sizes present in a soil is recognized by the procedure called **"mechanical analysis"**, in which the fractions of the soil whose particles lie between different limits of size are determined.
- The agreed international standards of size of different categories are as follows:

Gravel and stones particles →above 2mm in diameters
Coarse sand particles → from 2-0.2 mm in diameters

Fine sand Particles → from 0.2- 0.02 mm in diameters
Silt particles → from 0.02-0.002 mm in diameters
Clay particles → below 0.002 mm in diameters



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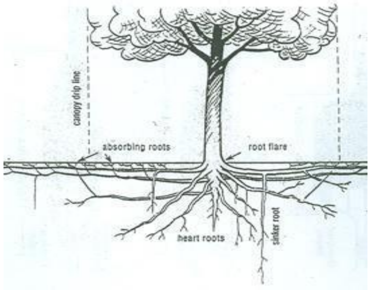
- All soils contain in fact particles belonging to more than one of these categories, the soil itself being named after the fraction which is preponderant' when soil consists of a good mixture of particles of widely different sizes with adequate humus fraction it is called loam.
- **In mechanical analysis** a sample of air-dried soil is firstly heated to 1000 C in an oven till it no longer loses water, and then heated to redness in a crucible or one a sheet of metal to burn away the humus. The mineral residue is then pounded in a mortar to reduce it to its elementary particles, and washed through a series of sieves, each with a mesh of definite diameter, to separate the coarser particles, and the successive fraction dried and weighed. This procedure of course destroys the structure of the soil, by breaking up the compound particles or "crumbs", so that it only gives information as to the proportions of the ultimate mineral particles of which it is composed .

Characters of soils of different textures:

- **Gravels**: are soils with a preponderance of large particles above 2 mm in diameter, practically always mixed with a coarse sand fraction and some finer particles as well. Aeration and percolation of water are extremely free. Gravel soils are unfavorable to plant life because of their dryness and poverty in nutrients, unless the ground water is high and carries nutrient salts. A gravel soil has the characters of coarse sand in extreme form.
- **Sandy soils**: have a preponderance of particles between 2mm. and 0.2 mm. in diameter (coarse sand) and between 0.2 - 0.02 mm. (fine sand). The particles are typically of silica (SiO_2). Percolation of water and aeration are free, the water holding capacity (in case of low humus) and power of raising water slight because the spaces between the particles are too wide. Hence sands are dry soils unless the ground water is high, and warm.
- They are light and easy to work but typically poor in nutrients because of deficiency in the finer particles with which the bases are associated, and because the free

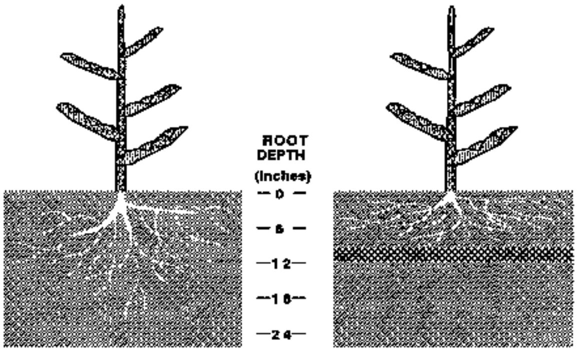
percolation of rain-water leads to very thorough leaching for this reason they are easily "**<u>podsolised</u>**" and quickly develop acidify.

- **Silt soils:** are intermediate between sands and clays in the size of their particles' They are favorable soils for vegetation because they have considerable water-holding capacity, while percolation, aeration and capillary rise of water are fairly free. The name is derived from the prevalent texture of alluvial soils (silts) laid down on the flood plains of rivers.
- **Clays**: are soils in which the particles below 0.002 mm in diameter, typically of hydrated alumino-silicates, are numerous enough to give character to the soil.
- Any soil with a proportion of 30 - 40 % or more of these fine particles would be **called a clay soil**. Clay soils have all the qualities opposite to those of sand: percolation of water is very slow or almost nil غير موجود , aeration defective and water-holding capacity very high.
- Clay soils are wet, heavy, difficult to be cold and "late" because they warm up slowly owing to the high water content.
- Under continued drought the clay colloid shrinks, cracks, and eventually “bakes" hard. These characters make clay soils physically unfavorable to many plants, and root systems tend to be shallow because of the difficulty of adequate aeration at greater depths.
- This effect can be well seen on clay grassland, where the grasses are all shallower rooting species, and in clay woods, where the roots of shrubs and trees tend to be concentrated in the "improved" surface soil, while in a sandy wood the roots of the woody plants are more spaced out vertically and reach a greater depth.



- On the other hand clay soils are often chemically favorable to plants because they may be rich in bases associated with the complex silicates; the basic ions free or adsorbed by the weathering complex' Clays are, however, sometimes deficient in essential nutrients, e.g. phosphates, and sometimes in bases also.

- Clays are much improved by an abundance of mild humus (mull) which "opens" and lightens the soil, and by calcium carbonate which flocculates the clay colloids so as to form "crumb structure" and secures better aeration and free movement of water



ROOTING DEPTH WITH NO PHYSICAL BARRIER BUT CHEMICAL BARRIER - ACIDIC SUBSOIL (LOW pH)

ROOTING DEPTH WITH PHYSICAL BARRIER - HARDPAN OR PLOWPAN, SUBSOIL ALSO ACIDIC

- **Loam soils:** Consisting of a good mixture of particles of different sizes, are the most favorable soils for the great majority of plants because they tend to combine the good qualities of the extreme types. Thus the **clay and humus fractions** → give consistency and water holding power and supply plant food, **the particles of medium size** → permit of the capillary rise of water, while **the sand particles** → facilitate aeration.

- The constitution of loams has a wide range according to the relative preponderance of one fraction or another:

- Thus we have **“heavy (clay) loams"**, **“<u>medium</u> loams”**, and **“light (sandy) loams"**. With an adequate supply of bases, especially calcium, plenty or mild humus and good water supply and drainage, medium loams are the ideal soils for all plants except highly specialized types adapted to extreme edaphic conditions.

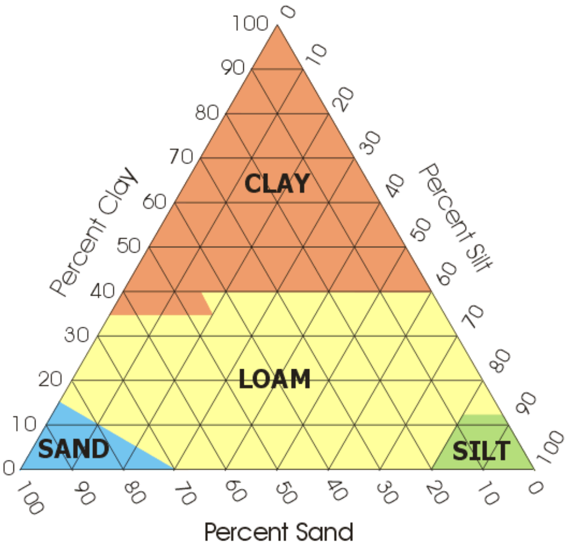
- **Limestone soils:** derived directly from lime-stones. A relatively pure limestone like the **chalk** (of 90% and in some cases nearly 100% of which consists of calcium carbonate), weathers by chemical <u>solution of the carbonate</u>, <u>not primarily by mechanical erosion</u>, though this may contribute where the rock is exposed in cliffs and scars for the most part gradual solution of the rock takes place below the carpet of vegetation and surface humus through the action of percolating rain-water containing carbonic acid.

- The result is the formation of a shallow soil consisting of the scanty residue of insoluble mineral particles and of surface humus, the whole saturated with calcium such shallow limestone soils are dry soils, because the percolating rain-water quickly escapes through the fissures of the rock below.

- They support **herbaceous plants** which can tolerate drought, including species which flourish on alkaline soils and cannot tolerate acid conditions.

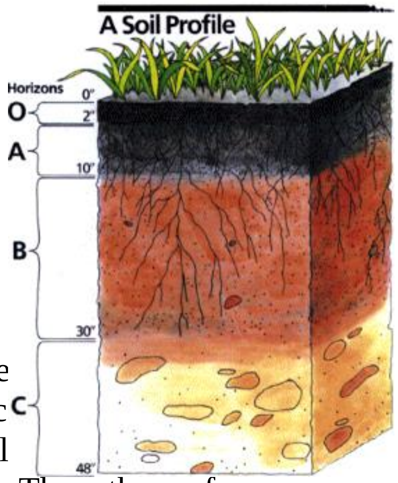
- Deeper soils are formed from lime-stones which contain a larger proportion of insoluble mineral particles and also, though much more slowly, flat horizontal surfaces of almost pure limes-tones like the chalk, where the very scanty insoluble constituents derived from a great thickness of dissolved rock have had time to accumulate in depth and are not removed by rain-wash down a steep slope.

Under such conditions the nature of the resulting soil depends on the nature of the insoluble material of which it is composed. If this is largely clay or silt, a good water-holding soil is produced, if it is largely sand, a light permeable soil.



Development of Soils

- The controlling factors in the development of soil are climate and vegetation. The features assumed by the soil in its development from infancy through youth, maturity, and old age vary with the environment.Thus, all mature soils developed on undulating or gently sloping surfaces and for long time undisturbed by injurious erosion, by deposit, or by the activities of man.
- Their characteristics not so much attributed to the kind of rock from which they originated as to the nature of the climate in which they have developed.
- Soils tend to show a similar sequence of horizontal layers, irrespective of the underlying rock, the latter causing only minor differences.
- These layers occur in a definite sequence and differ from one another in one or more easily discernible features, such as color, lime content, texture, structure, and compaction. A vertical cut through these various horizons is termed "**soil profile**".



- The nature of the several layers has a profound effect upon the water, air, and nutrient relations of the soil and consequently upon root extent and distribution and nature of the soil cover.

Soil profile:

- Most soils consist of particles of various sizes, chemical constitution and degree of solubility. During long periods of time, calcium carbonate and other soluble materials are leached from the surface soils and carried down to lower layers or to ground water and consequently out of the soil.
- The finer, insoluble soil particles (colloidal clay, etc.) are also me downward (under those types of soil formation in which they bec variable depths which depend largely upon the amount of rainfal with which the water is absorbed and transpired by the vegetation. Thus, the surface layers of a mature soil are poorer in soluble salts as a result of leaching and are coarser grained because of eluviations or washing down of the colloidal clay,

- ***These layers constitute***
- A, the zone been carried is designated
- B, the zone of concentration (accumulation).
- E, at greater depths there is third zone, where neither extraction nor accumulation has occurred it is the mother rocks zone.
- The A and B zones or horizons constitute the solute produced by soil building processes.

- The c horizon is the weathered parent material or unconsolidated rock from which (usually) the soil has developed. Each soil zone or horizon has a distinct color, texture, and structure.

Soil Horizon	***Description***	***Horizon Depth*** (Measurements are approximate)
O Horizon	Mainly twigs, leaves and other organic matter. Not all soil has an O horizon.	0.5 in. - 1 in.
A Horizon	Also known as the topsoil, essential for plant growth. The A Horizon is composed of mainly nitrogen, phosphorus and potassium. Has a dark brown color and a light texture.	1 in. - 2 ft.
B Horizon	Also known as the subsoil. Has few plant nutrients and a higher clay content. Usually the subsoil has a brighter color and a high salt content.	2 ft. - 4 ft.
C Horizon	Also known as the substrata. The C horizon (also known as the weathered parent material) is often a reddish-tan color and unaltered by rainfall or other natural conditions.	5 ft. - varies greatly
R Horizon (Bedrock)	Also known as the fresh parent material. Bedrock is usually a light tan color.	In the Central Valley, bedrock can be found as deep as 5,000 ft.

The soil is a natural body in dynamic equilibrium with its environment. Thus we have:

l- **Young soil**: not developed (there is unbalancing between soil and the surrounding conditions, inherited characters only)
2- **Mature soil**: developed (an equilibrium state occurs between the soil and the environment .
3- **Zonal soil**: its profile show different zones
4- **A-zonal soil**: without any zones (young soils)
5- **Transported soil**: the soil transported by wind (duns) or rivers (Nile valley)
6- **Residual soil**: formed in its place (where the parent rocks are present).

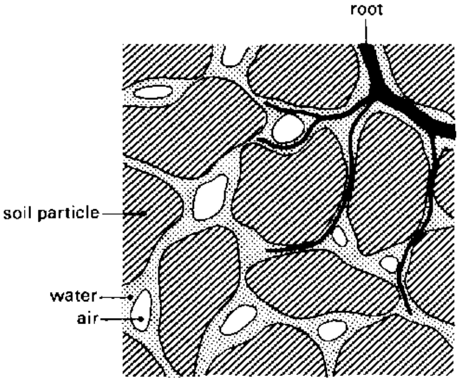
Composition of soil

The components of a mature soil can be classified into four categories:

1 - A matrix of **mineral particles** derived by varying degrees of breakdown of the parent material.

2- An **organic component** derived from long-and short-term additions of material from plants, animals and microorganisms above and below ground.

3- **Soil water** held by capillary and adsorptive forces both between and at the surface of the soil particles, its amount varying with the balance between precipitation, evapo-transpiration loss and drainage. Soil water is in reality a dilute solution of many different organic and inorganic compounds and forms the immediate source of plant material nutrients.



4- The **soil atmosphere** occupies the pore space between soil particles which, at any time, is not water-filled.

The organic fraction of the soil "Humus"

- Practically all soils contain organic material derived from the disintegration of plants or parts of plants such as dead leaves, roots and rhizomes, with a small addition from animal excreta or dead bodies.
- A part from highly exceptional soils, such as those accumulating below maritime "bird cliffs" or "bird rocks" inhabited by thousands of sea birds, which are largely formed of the birds droppings, the animal contribution is insignificant compared with the great bulk of plant material.
- ***The term <u>humus</u>*** is usually applied to the whole complex of disintegrating and decaying organic material in or on the soil, but sometimes it is restricted to the brown substance, soluble in acidified water, which is formed as a late result of the processes of disintegration and chemical change of the organic debris.
- The soils of habitats such as deserts, in which the vegetation is always sparse, and new soils, freshly formed from inorganic material, contain the least humus, mature well-vegetated soils the most.

- In a raw soil, freshly formed from rock or alluvium, humus begins to accumulate directly plants of any kind settle upon it, and a certain contribution may also be made by windborne particles of organic substance.
- In many soils earthworms are important agents in incorporating dead leaves and stems with the soil. They drag them down into their burrows, and constantly pass large quantities of humus through their bodies' disintegrating and partially digesting the organic matter. They are aided in the work of disintegration by other small soil animals, and also by soil fungi and bacteria.
- Eventually the disintegrated and decomposed organic substance is finally broken up by bacteria of different kinds into carbon dioxide, water and simple salts, which break up in water into **anions** (N, S, P) and **cations**, (Ca^{+2}, Mg^{+2} and K^{+},), all of which elements are necessary ingredients of plant food.
- ***Nitrification and its conditions***
- A most important chemical soil process as regards the food of the higher plants is **nitrification**, the conversion of NH_4^- salts into NO_2^- and then into NO_3^-, the last process being carried out by the so called **nitrifying bacteria**.
- The great majority of green plants absorb their nitrogen in the form of NO_3^-. These processes take place most freely and rapidly in soils with a fairly high "base status" and moderate water content, in the presence of plenty of free oxygen and at a moderately high temperature, i.e., in rich, moist, warm' well aerated soils.
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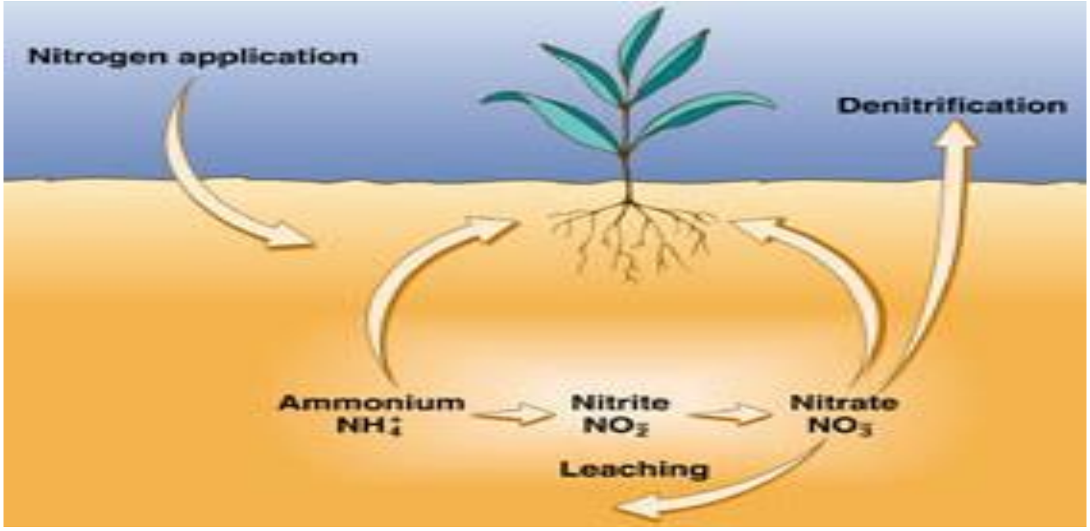
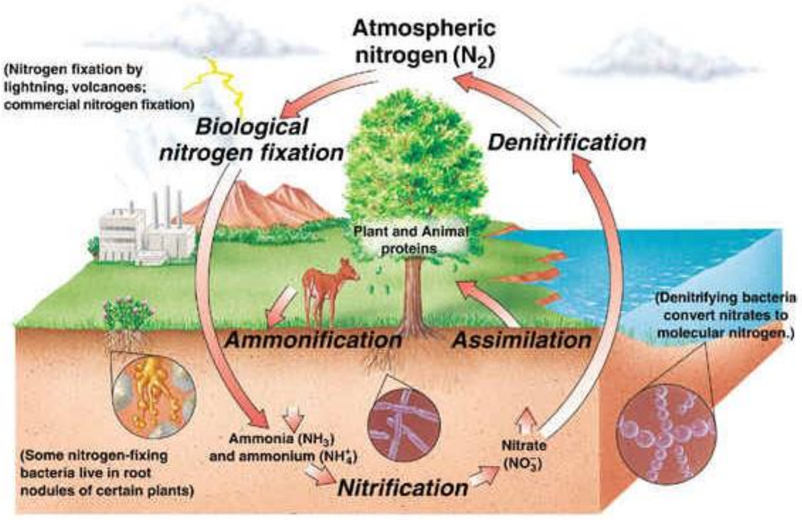


Nitrogen Cycle



Mull

- The kind of humus formed where the processes described are free is known as ***mull*** (mild humus), under these conditions the humus turnover is quick when the temperature is sufficiently high. Humus is formed in quantity, and rapidly' because the favorable conditions for the growth of plants give an abundant supply of plant material and this is rapidly decomposed because of the favorable conditions for the activity of the soil organisms.
- In this way an ample supply of the ions of the mineral salts which had been licked up in the plant tissues is set free and made available again as plant food.
- Mull is therefore characteristic of the fertile soils of high base status already described. It is well incorporated in the soil and becomes combined with the compound particles of colloid clay to form the reactive weathering complex.
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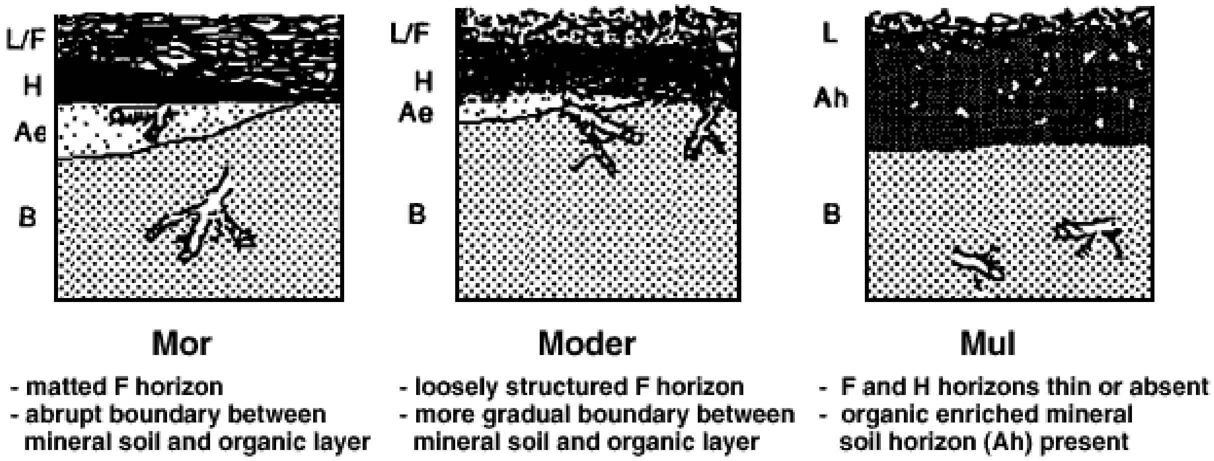

Mor

<u>There are several conditions leading to the production of mor.</u>

1. **First** it tends to be formed in soils derived from rocks which are very poor in bases, such as many of the siliceous rocks and some of the sandy soils.
2. **Secondly** it is formed especially in a cold damp climate where the conditions are unfavorable for the active life of many of the mull-producing soil organisms.

- **Thirdly** high rainfall leads to through leaching of the surface layers of soil, carrying down the soluble mineral salts to lower layers, especially quickly on highly permeable soils, and thus increasing the poverty of the upper layers and leading to the formation of mor .
- Where one or more of these conditions prevails the formation of humus from litter is slowed down and partly decomposed litter tends to accumulate, becoming highly acid because the bases 'contained in the decomposing plant substances are leached out and the organic acids are not neutralized.
- The excess of hydrogen ions renders the humus substances extremely mobile and heavy rain carries them down to lower levels, especially in a permeable soil.
- The solubility, and consequent mobility of mor humus are conspicuously shown by the brown colour or moorlands streams draining from acid peaty soils, especially when the streams are in **spate**.
- In the hilly and mountainous regions, all the conditions leading to the production of mar-siliceous rocks poor in bases, a cool damp climate and heavy rain are frequently combined, so that mor soils are the prevailing type over wide areas.

The soil fauna and flora of mar are totally different from those of mull:

- Earthworms and other invertebrates active in the formation of mull are absent, and instead of the wide range of bacteria, including the nitrifying bacteria, present in mull, certain fungi especially **Hymenomycetes**, are the predominant "**saprophytic**" forms of lower plant life.
- The absence of nitrifying bacteria means that no nitrates are produced, and ammonium compounds are the main form of combined nitrogen available for the nutrition of the higher plants.
- The mor soils with complete absence of nitrates are found to have a pH value **below 3.8**, which appears to be a critical limit separating mor from mull in several soil series but there are soils less acid than this which show at least incipient mor formation and may be transitional between the two types.

- ***Soil water content***

  Water is important to plant in many ways:-

  1- It is a component of Protoplasm.

  2- Water and CO_2 are essential in building plant foods.

3- It usually constitutes 70 to 90 percent of the weight of herbaceous plants.
4- All substances that enter plant cells must do so in solution.
5- Water is the great solvent.
6- It serves as a medium of transport of nutrient and foods from place to place.
7- It keeps the cells turgid, a condition essential for their normal functioning.
8- It serves to prevent excessive heating of the plant, acting as a buffer in absorbing the heat generated by chemical reactions taking place in the plant.

The amount of water contained in a given soil at any moment depends upon several factors. We have seen that the water relations of soils of different textures are very different, the amount of water retained by the soil depending on the size of the soil particles and the amount of humus present.

With my best wishes

Prof.Dr./ Noha Ahmed El-Tayeh Ali