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Topic- Factors affecting photosynthesis.

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Factors affecting photosynthesis

The following points highlight the ten major factors affecting photosynthesis. The factors are: 1. Light 2. Carbon-Dioxide 3. Water 4. Nutrient Supply 5. Temperature **6.** Oxygen Concentration 7. Chemical Compounds 8. Chlorophyll Content 9. Leaf Anatomy 10. Protoplasmic Factors.

Factor # 1. Light:

A study of the effect of light on the rate and quantity of photosynthesis would have to include light reflected, absorbed and transmitted; intensity, quality and duration of available light, and destructive effects of light.

The plant is capable of using only a very small portion of the incident electromagnetic radiation that falls on a leaf. This radiation is absorbed by the pigment complex of the leaf. Each pigment has its own absorption spectrum. The chlorophylls absorb heavily in the blue and red region of the spectrum and β-carotene mostly in the blue region. Most of the light is being reflected in the green region, giving a leaf the green colour. The greater absorption of light is found in thicker leaves with, a lower percentage of transmitted light as compared to thinner leaves.

Light Intensity:

There may be a direct relationship between the rate of photosynthesis and the intensity of light, provided that no other factor is limiting. For example, on bright sunny days the carbon dioxide concentration of the atmosphere is usually the limiting factor, not light intensity.

However, on cloudy days light may be the limiting factor. Heinicke and Childers (1937) have found that the rate of photosynthesis steadily increased with light intensity up to about full sunlight even through saturation intensity for a single exposed leaf would be sufficiently lower. The need for higher light intensities for maximum photosynthesis of an entire tree is due to partial illumination of the inner leaves.

Both quality and intensity of light influence photosynthesis. Light between wavelength of 400 nm and 700 nm is most effective, for photosynthesis. This light is called photosynthetically active radiation (PAR).

Photo-Oxidation:

When the light intensity is increased beyond a certain point, the cells of the leaf or other photosynthesizing organ become vulnerable to chlorophyll-catalysed photooxidations. With the result, many more chlorophyll molecules become excited than can be utilized causing the bleaching of chlorophyll and inactivation of important enzymes.

The presence or absence of carotenoids and the concentration of carbon dioxide also influence the amount of photo-oxidation. The carotenoids have a protective role in photo-oxidation. With high concentrations of carbon dioxide, the consumption of oxygen of photo-oxidation takes place at much higher light mtensities.

Light Quality:

White light, that comes from the sun, is composed of different wave lengths, ranging from the relatively long wave or red light (700 nm) through successively shorter waves to violet light (440 nm). When passed through a glass prism, white light is resolved into seven colours. The band of colours is the visible spectrum. The complete visible spectrum is composed of red orange, yellow, green, blue, indigo and violet colours.

The wave length of light that we are unable to perceive with our eyes, beyond the red and still longer, invisible rays, the infrared; and beyond the violet are shorter invisible rays, the ultraviolet. As we know, the absorption spectrum of chlorophyll shows a sharp peak at the red end and a wider but less definite peak at the blue end.

Green light is mostly transmitted or reflected and therefore, is not utilized in photosynthesis. Red and blue lights are effective in photosynthesis. Hoover (1937) while working on wheat plants found that the wavelength (655µm) in the red is most effective and a wave length (440 µm) in the blue to be the second most effective in photosynthesis.

Duration of Light Period:

It is assumed that a greater quantity of photosynthesis will take place in a plant exposed to longer periods of light. In general plant carries on much photosynthesis if it is provided with light for 10 to 12 hours per day.

Bohning (1949) found that the leaves on young apple trees exposed to a continuous illumination and the usual atmospheric concentration of CO_2 photosynthesize at an undiminished rate of periods of at least 18 days without any noticeable damaging effect on the plant.

Factor # 2. Carbon-Dioxide:

The carbon dioxide, which constitutes on the average only about 0.03 per cent by volume of the atmosphere, plays a role of the greatest significance in the biological world. As a result of the photosynthetic activity of green plants, the carbon dioxide from the atmosphere becomes chemically bound for indefinite period of the organic molecules which are the basis of all life.

Carbon Dioxide Supply:

The green plants utilize the atmospheric carbon dioxide, while the other sources supply the gas to the atmosphere. Carbon dioxide is continually being returned to the atmosphere as a product of the respiration of plants and animals.

The organic residues of plants are decomposed as a result of activities of bacteria and fungi. During decay the carbon of these residues is released in the carbon dioxide as a result of the metabolic activities of these organisms and escapes into the atmosphere.

The respiration of the soil bacteria alone results in a greater return of carbon dioxide to the atmosphere than the respiration of all animals. Carbon dioxide is also released into the atmosphere from volcanoes, mineral springs, and in the combustion of coal, oil gasoline, wood and other fuel materials.

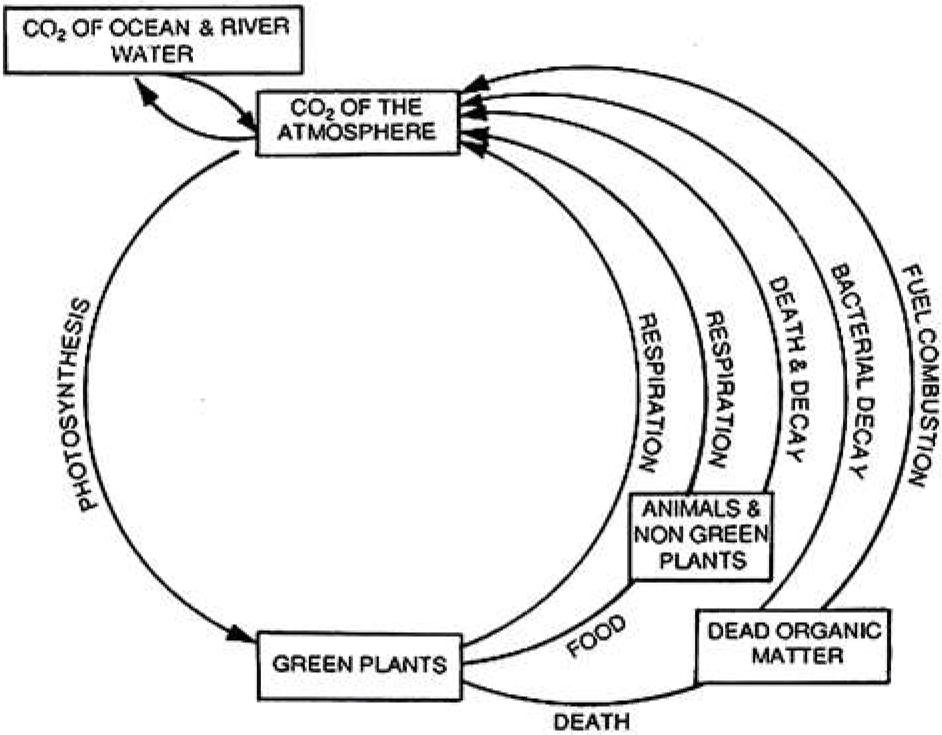

Fig. 5.14. Carbon cycle in nature.

Oceans are much more important reservoirs of carbon than the atmosphere. The marine plants consume carbon dioxide in photosynthesis and release carbon dioxide in the process of respiration. There is a constant exchange of carbon dioxide between the ocean and the atmosphere. On theoretical grounds it is assumed that the carbon dioxide concentration of the atmosphere is more or less maintained in dynamic equilibrium with that of the oceans.

Carbon dioxide that escapes from the oceans whenever its atmospheric concentration falls below the usual value, and dissolves in the oceans whenever a contrary shift in atmospheric carbon dioxide concentration occurs. The maintenance of such a dynamic equilibrium between the oceans and the atmosphere is the principal factor for the constant value of carbon dioxide concentration of the atmosphere.

Absorption of Carbon Dioxide:

Carbon dioxide in the air surrounding the leaves ultimately reaches the chloroplasts. Its inward diffusion path is through the stomata to the intercellular spaces, through walls of palisade and spongy parenchyma cells to the cytoplasm and thereafter into the chloroplasts.

The walls of palisade and spongy parenchyma possess water. Carbon dioxide dissolves in water and ultimately passes through the walls in aqueous solution.

Carbon Dioxide Concentration:

If light intensity and temperature are favourable, the carbon dioxide of the atmosphere limits the rate of photosynthesis.

The workers like Kreuslar (1887), Brown and Escombe (1902) and Pantanelli (1903) investigated that there is an increase in the rate of photosynthesis with an increase in the concentration of carbon dioxide at the lower levels of carbon dioxide concentrations.

A decline in rate was observed in higher concentrations. Blackman and his co-workers claimed that after an optimum concentration is reached, the rate of photosynthesis remains constant over a wide range of carbon dioxide concentrations.

It has been demonstrated experimentally that at usual temperature and light intensities, artificial increase of carbon dioxide up to a concentration of 0.5 per cent may give an increased rate of photosynthesis, but only for a limited period. It appears that the high level of carbon dioxide is injurious to plants.

Factor # 3. Water:

Water is one of the raw material utilized in the process of photosynthesis. In land plants, the soil is the source of water. Only about one per cent or less of the water absorbed by the roots is actually used in photosynthesis.

Investigators noted reduction in the rate of photosynthesis in water deficient soils. These inhibitory effects are primarily because of decreased hydration of the protoplasm and closing of stomata.

Removal of water from protoplasm affects its colloidal structure and therefore, affects metabolic processes such as photosynthesis, respiration. According to Rabinowitch (1945), photosynthesis is more sensitive to dehydration than other metabolic processes, such as respiration.

Many workers think that the primary factor in the retardation of photosynthesis by dehydration is closing of stomata. When a water deficit occurs in a plant it causes the closing of the stomata, and therefore, there is a decrease in the absorption of carbon dioxide.

Since carbon dioxide concentration of the atmosphere is usually low enough to be the limiting factor in the photosynthesis under natural conditions, a decrease in its absorption, therefore, slows down the rate of photosynthesis.

Factor # 4. Nutrient Supply:

Among various nutrients, nitrogen has direct relationship with photosynthesis. As we know, nitrogen is a basic constituent of chlorophyll and all enzymes involved in carbon reactions, any reduction in nitrogen supply has an adverse effect on photosynthesis.

The major enzyme of carbon metabolism in plants is Rubisco, which alone accounts for more than half of the total leaf nitrogen. In general, all essential elements affect the rate of photosynthesis.

Factor # 5. Temperature:

Photosynthesis can take place over a wide range of temperature. Plants of cold climates photosynthesise at much lower temperatures than do those of warm climates. The photosynthesis takes place in certain evergreen species of cold regions, even at temperatures below than 0°C. It has been reported to occur in some species of conifers at temperatures as low as -35°, and in some kinds of lichens at -20°C.

Tropical plants normally do not photosynthesize below about 5°C. On the other hand algae in the water of hot springs may carry on photosynthesis at a temperature as high as 75°C. Many semi-desert and tropical species can withstand air temperatures of 55°C. Most ordinary temperate climate plants, however, photosynthesize best between temperature of 10° and 35°C.

If there is adequate light intensity and a normal supply of carbon dioxide (i.e., no factor is limiting), the rate of photosynthesis of most ordinary land plants increases with rise in temperature up to a point (usually 25°C) which varies somewhat from one kind of a plant to another; above this range there is rapid decline in the rate of photosynthesis primarily form injurious effects of higher temperatures on the protoplasm.

At these higher temperatures the time of exposure is of importance.

The higher the temperature the sooner the decline in photosynthetic rate. The decline in the rate of photosynthesis with time particularly marked at higher temperatures, is evidence of the increasingly limiting effect of some internal factor generally called the "time-factor". As regards the nature of this time factor, it is possible that it may represent the composite influence of several internal conditions.

They are as follows:

(i) An inactivation of enzymes at higher temperatures.

(ii) The accumulation of the end products of the reaction which may exert a retarding effect on the rate of photosynthesis.

(iii) Failure of the diffusion of carbon dioxide toward the chloroplasts to keep pace with its use in photosynthesis.

(iv) Similar time factor effects are present in the temperature relations of other plant processes such as respiration and growth.

Factor # 6. Oxygen Concentration:

In most plants, increase in the oxygen concentration results in a decrease in the rate of photosynthesis. The normal atmospheric concentration of oxygen is high enough to induce a lower rate of photosynthesis than obtains at lower concentration of oxygen. This is demonstrated by the work of McAlister and Myers (1940) showing the effect of high and low concentrations of oxygen on the rate of photosynthesis of wheat plants.

The explanation of this seems to be that oxygen actually exerts as direct inhibitory effect on photosynthesis, and the greater the concentration of oxygen the greater this effect.

Contrary to above statement the energy product in oxygen respiration is necessary for photosynthesis. Even small amount of this energy, may supplement light energy.

Factor # 7. Chemical Compounds:

Many different kinds of chemical compounds have direct or indirect effect upon the rate of photosynthesis. Especially the effects of certain substances are noticeable which markedly influence the rates of photosynthesis when present only in minute quantities. Among these chemical compounds are hydrocyanic acid, hydroxylamine, hydrogen sulphide and certain compounds containing the iodoacetyl radical.

Narcotics such as chloroform, ether and urethans, exert retarding or inhibitory effects on photosynthesis when present in very low concentrations.

Factor # 8. Chlorophyll Content:

Chlorophyll is indispensable for photosynthesis. Scientists, devised the photosynthetic number (assimilation number). This assimilation number is the number of grams of carbon dioxide per hour per gram of chlorophyll. Other investigations show that there is not proportional relationship between chlorophyll content and photosynthesis in the leaves of vascular plants.

Factor # 9. Leaf Anatomy:

The rate of photosynthesis is also influenced by the anatomy of the leaf. Here the structural features of the leaf influence the amount of carbon dioxide that reaches the chloroplasts.

The size, position and structure of the stomata, the size and distribution of the intercellular spaces, the relative proportions and distribution of palisade and spongy layers, thickness of the cuticle and epidermis, the amount and position of sclerenchyma, the presence of epidermal hairs, the arrangement of mesophyll cells, distribution and efficiency of vascular system, position of chloroplasts in the cells, all influence the rate of photosynthesis.

The effect of the leaf anatomy upon the rate of photosynthesis is because of influences upon the rate of carbon dioxide entry, upon the light intensity penetrating to chlorenchyma cells, upon the turgidity of leaf cells and upon the rate of translocation of solutes from green cells.

Factor # 10. Protoplasmic Factors:

The rate of photosynthesis is also affected by protoplasmic factors. The most important protoplasmic factor is the enzyme complement of the protoplasmic system. A number of enzymes play an important role in the process of photosynthesis. The hydration of protoplasm is essential. If the cells lack water and protoplasm is dehydrated, the rate of photosynthesis slows down.