Factors Affecting Photosynthesis

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- The rate of photosynthesis is very important in determining the yield of plants including crop plants.
- Photosynthesis is influenced by several factors including both internal and external factors.

### External Factors
- Carbon dioxide
- Light
- Temperature
- Water
- DCMU

### Internal Factors
- Chlorophyll content of leaves
- Protoplasmic factor
- Accumulation of byproducts
- Leaf anatomy
- Age of leaf
- Hormones

- An understanding of these photosynthetic factors is essential in order to estimate the rate of photosynthesis.
- During photosynthesis, all these factors simultaneously affect the rate of photosynthesis or CO₂ fixation.
- However, among these factors, usually one factor is the major cause which limits the rate of photosynthesis.
- Hence, at any point, the photosynthetic rate will be determined by the factor available at sub-optimal levels.
- When several factors affect any biochemical process, Blackman’s law of limiting factors comes into effect.

**FACT**

A limiting factor is a factor which is deficient to such an extent that an increase in its value directly increases the rate of the process.

- According to Blackman’s law of limiting factors, ‘When a process is conditioned as to its rapidity by a number of separate factors, the rate of the process is limited by the pace of the slowest factor’.
- This implies that if more than one factor affects a chemical process, then its rate will be determined by a factor which is nearest to its minimal value. It is the factor which directly affects the rate if its quantity is changed.
- Example: Despite the presence of a green leaf and optimal light and CO₂ conditions, the plant may not photosynthesise if the temperature is very low. This leaf will start photosynthesising if provided with the optimal temperature.
External Factors Affecting Photosynthesis

- Some of the external factors which affect the rate of photosynthesis include carbon dioxide, light, temperature, water and DCMU (3-(3,4-dichlorophenyl)-1,1-dimethylurea).

Carbon Dioxide
- The concentration of CO₂ in natural air varies between 0.03% and 0.04%.
- Increase in the concentration of CO₂ up to 0.05% increases CO₂ fixation.
- A slight rise beyond this concentration can have damaging effects over long periods.
- There is a difference in the photosynthetic response to the available CO₂ concentration in C₃ and C₄ plants.
- In C₃ plants, the rate of photosynthesis increases with an increase in CO₂ concentration up to about 500 ppm (500 μL/L).
- In the absence of other factors, the increase in the rate of photosynthesis in C₃ plants is due to
  i. Availability of substrate in higher concentration for carboxylation reaction
  ii. Reduced photorespiration because of more availability of CO₂ to RuBisCO
- Even in C₄ plants, the rate of photosynthesis increases with an increase in CO₂ concentration.
- However, C₄ plants attain saturation at a much lower CO₂ concentration, i.e. 360 ppm (360 μL/L), whereas C₃ plants attain saturation at a CO₂ level of about 500 ppm (500 μL/L).
At the current level of CO\(_2\) concentration, the rate of photosynthesis is optimum for C\(_4\) plants and lower for C\(_3\) plants.

As the concentration of CO\(_2\) is about to reach 600 ppm (600 μL/L) by 2020, only C\(_3\) plants would be benefited.

C\(_3\) plants respond to higher CO\(_2\) concentration by showing increased rates of photosynthesis leading to higher productivity.

This principle has been used for greenhouse crops such as tomatoes and bell pepper. They are allowed to grow in carbon dioxide-enriched atmosphere which leads to higher yields.

**Light**

- The ultimate source of light for photosynthesis is solar radiation.
- The quality, intensity and duration of light affect the rate of photosynthesis.

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**Quality of Light**

- Light between the wavelength of 400 nm and 700 nm is the most effective for photosynthesis and this light is called photosynthetically active radiation (PAR).
- It is because the different rays of light are not absorbed equally by the chlorophyll.

**Intensity of Light**

- Under low light intensity, the rate of photosynthesis is low.
- As the intensity of light increases, the rate of photosynthesis increases.
- At very high light intensities, the rate of photosynthesis decreases.

**Duration of Light**

- The extent of photosynthesis is more when a plant is exposed to long periods of light.
- Uninterrupted and continuous photosynthesis for relatively long periods of time may be sustained without any visible damage to the plant.
Temperature
- In the presence of abundant light and carbon dioxide, the rate of photosynthesis increases with a rise in the temperature till it becomes maximum. After that, there is a decrease in the rate of the process.
- The rate of photosynthesis is maximum at an optimum temperature of 25–30°C.
- In desert plants such as _Opuntia_, photosynthesis occurs at a temperature of about 55°C. This is known as maximum temperature.
- In plants such as lichens and certain conifers, photosynthesis begins at a temperature as low as −20°C and −35°C. This is known as minimum temperature.

Water
- An increase in the water content of the leaf results in an increased rate of photosynthesis.
- Water indirectly exerts a limiting effect on the rate of photosynthesis.
- This is mainly because water helps in maintaining the turgidity of the assimilatory cells and the proper hydration of their protoplasm.
DCMU

- DCMU (3-(3,4-dichlorophenyl)-1,1-dimethylurea) is a very specific and sensitive inhibitor of photosynthesis.
- It blocks the plastoquinone-binding site of photosystem II and prevents the flow of electrons from photosystem II.
Internal Factors Affecting Photosynthesis

- Some of the internal factors which affect the rate of photosynthesis include the chlorophyll content of leaves, protoplasmic factor, accumulation of by-products, leaf anatomy, age of the leaf and hormones.

**Chlorophyll Content of Leaves**
- The rate of photosynthesis is not proportional to the quantity of chlorophyll present in leaves.
- This is because chlorophyll merely acts as a biocatalyst, and so, even a small quantity is quite enough to maintain a large bulk of the reacting substances.

**Protoplastic Factor**
- Plants which are transferred from dark to light do not start photosynthesis immediately.
- It is due to some internal factors present in the protoplasm which prevent plants from photosynthesising.

**Accumulation of By-products**
- Photosynthesis takes place continuously as long as the concentration of the products formed is maintained.
- The final product of photosynthesis is sugar and its accumulation in the cells slows down photosynthesis.

**Leaf Anatomy**
- The thickness of the cuticle and epidermis of the leaf, the size and distribution of intercellular spaces, the distribution of stomata and the development of chlorenchyma and other tissues also affect the rate of photosynthesis.

**Age of Leaf**
- As a leaf develops, the rate of photosynthesis increases with age, till the leaf is fully expanded.
- The rate of photosynthesis declines after this because ageing and senescence bring about deactivation of enzymes and degeneration of chlorophyll.

**Hormones**
- Auxins, cytokinins and gibberellins stimulate photosynthesis.
- Abscisic acid reduces the rate of photosynthesis because of closure of stomata.