

PHOTOSYNTHESIS

11.1 THE C₂ PHOTO RESPIRATORY CARBON OXIDATION (PCO) CYCLE

All land plants have an additional metabolic activity and lose a considerable amounts of their photosynthates as CO₂ with in a few seconds of its being fixed. It occurs when plants are illuminated. This process of CO₂ release is light dependent and because of its otherwise superficial resemblance to respiration, it has been given the name Photorespiration. During the process O₂ is consumed and CO₂ is generated in light. It is independent of mitochondrial respiration but occurs in chloroplasts and peroxisomes and only a few reactions occur in mitochondria. However, unlike true respiration it performs no useful function in making energy available to the plant. Instead its occurrence leads to loss of energy and this is responsible for a considerable reduction in the yield of many of the crops.

Definition: Photorespiration means evolution of CO₂ by green leaves in light.

11.1.1 Mechanism:

RuBISCO is a by **bifunctional enzyme** capable of carboxylation as well as oxygenation of RuBP. The operation of the PCO cycle involves cooperative interactions between three organelles, Chloroplasts, mitochondria and peroxisomes.(Fig.13)

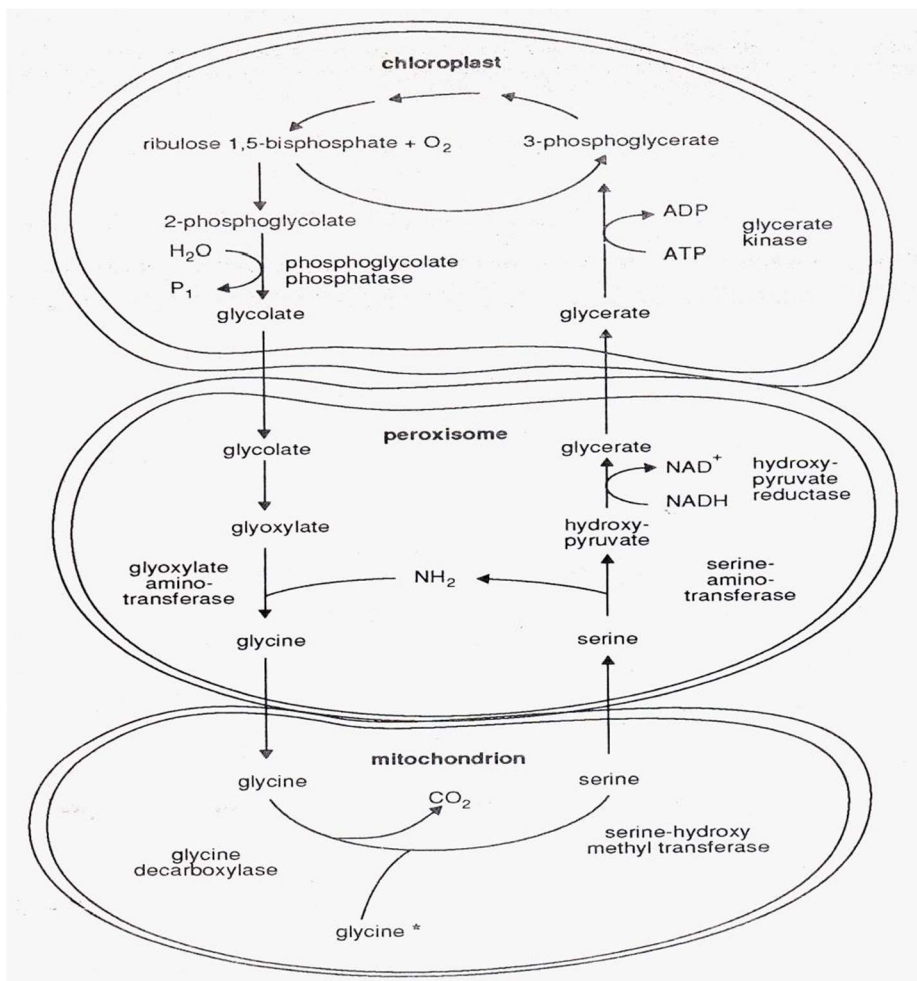


Figure.13

The oxygenation of RuBP results in the formation of 2-phosphoglycolate and 3-phosphoglycerate. The phosphoglycolate is rapidly hydrolyzed to glycolate by a specific enzyme phosphatase. Glycolate leaves the chloroplast and diffuses to peroxisome. There it is oxidized by glycolate oxidase to glyoxylate and hydrogen peroxide. The peroxide is destroyed by the action of catalase and glyoxylate undergoes transamination and the product is the amino acid **glycine**.

Glycine leaves the peroxisomes and enters mitochondria, where two molecules of glycine are converted to serine. **Glycine is thus, the immediate source of the photo respiratory CO₂**. Serine leaves the mitochondrion and enters peroxisome, where it is converted first by transamination to hydroxy pyruvate and then by reduction to glycerate.

Finally, glycerate reenters the chloroplast, where it is phosphorylated to yield 3-phosphoglycerate.

11.1.2 Significance:

Photorespiration is a response to the low CO₂/O₂ ratios prevalent in the present day atmosphere and has no functional role. Another possible explanation is that photorespiration is necessary under conditions of high light intensities and low CO₂ concentration (e.g. when stomata are closed because of water stress) to dissipate excess ATP and reducing power from the light reactions, thus preventing damage to the photosynthetic apparatus. Today, there is no conclusive evidence for the role of photorespiration in the carbon metabolism of the leaf.

Many plants do not photo respire, this is not because that RUBISCO have different properties, rather, it is a consequence of interesting mechanisms that concentrate CO₂ in the RUBISCO environment is in the case of C₄ and CAM plants. (CO₂ concentration mechanism)

11.1.3 Energy requirement

Oxygenation of ribulose bis phosphate and operation of PCO cycle consumes 2ATP and 2.5 NADH for each ribulose bisphosphate oxygenated.

11.2 FACTORS AFFECTING PHOTOSYNTHESIS

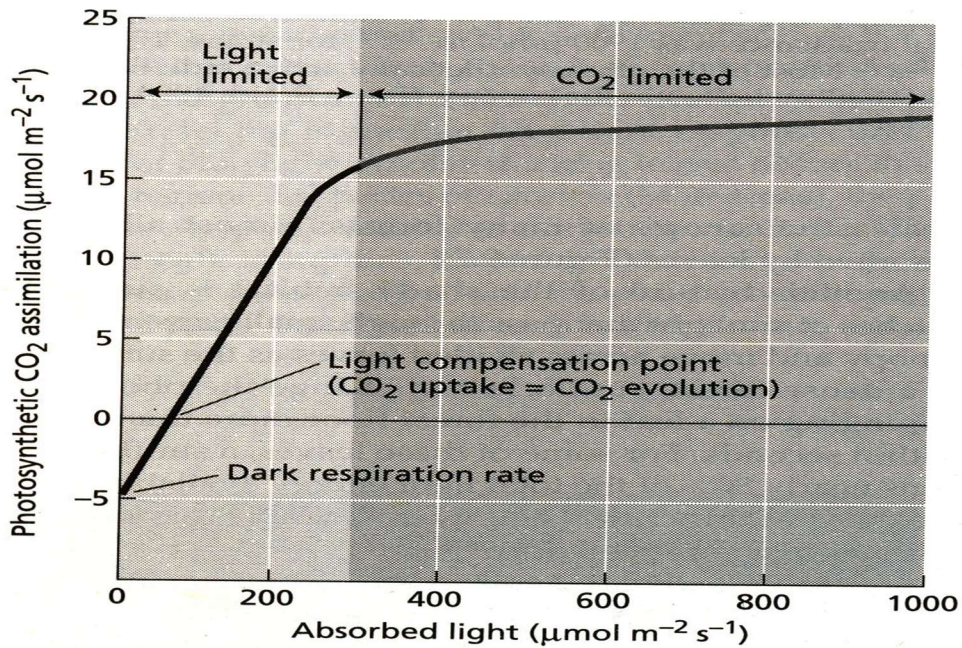
Many plant and environmental factors influence photosynthesis such as light, CO₂, temperature, availability of water as well as plant age and genetics.

11.2.1 LIGHT

The linear portion of light response curves of photosynthesis represent the part of the process in which photosynthesis is strictly light limited. Under this condition, each increment in light elicits a proportional increase in photosynthetic rate, resulting in a

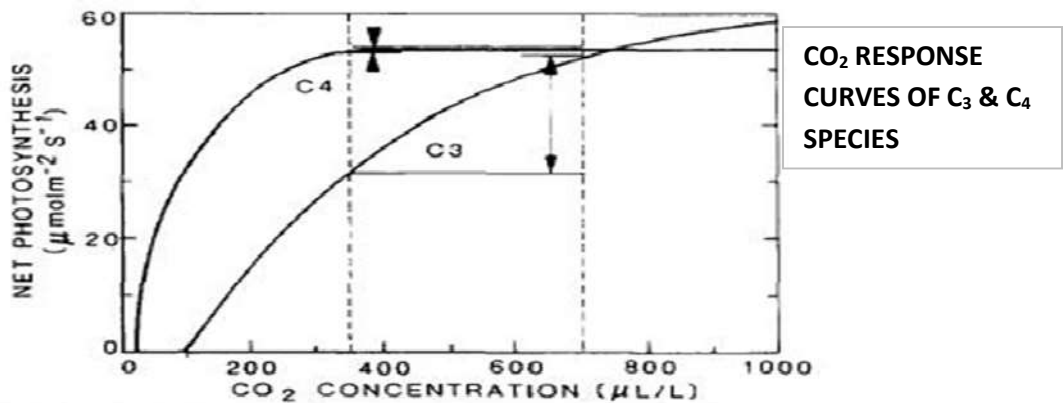
linear relationship between photosynthetic rates and photon flux densities. At higher photon flux densities, the photosynthetic response to light starts to level off and reaches saturation. Once saturation is reached, further increases in photon flux densities no longer affect photosynthetic rates, indicating other factors such as RUBISCO activity or the metabolism of triose phosphates, have become limiting.

In the Dark, CO₂ fixation is negative and there is net CO₂ evolution from the leaf because of respiration. As the photo flux density (availability of light energy) increases net CO₂ evolution decreases, after it reaches Zero, the plants shifts to net CO₂ fixation. The Photon flux density at which net CO₂ exchange in the leaf is zero is called **light compensation point**. The light compensation points of sun plants are high in the range of 10-20 u mol m⁻² S⁻¹ where as corresponding values for shade plants are low in the range of 1-5 u mol m⁻²S⁻¹. The values for shade plants are lower because respiration rates in shade plants are very low, so little photosynthesis suffices to bring the rates of CO₂ evolution to zero.



LIGHT RESPONSE CURVE

11.2.2 CARBON DIOXIDE: Carbon dioxide is a trace gas in the atmosphere constituting approximately 390ppm.



Classical net photosynthetic curve for C₃ and C₄ species. Dashed vertical lines at 350 and 700 μ lit/lit

mark the current CO₂ level and the doubled concentration predicted to be reached some time late in the next century. Arrows indicate incremental rise in net photosynthesis due to the CO₂ doubling.

In plants with CO₂ concentrating mechanisms which include C₄ and CAM plants, the CO₂ concentrations at the carboxylation sites are often saturating. So a C₄ plant such as corn cannot increase its photosynthetic performance with the increase in atmosphere CO₂ concentrations. In the C₃ Plants, on the other hand, increasing C_i levels (C_i partial pressure of CO₂ in the inter cellular spaces of leaf) continue to stimulate photosynthesis over much broader range.

Also markedly different in C₃ and C₄ plants is the CO₂ compensation point, the CO₂ concentration at which CO₂ fixation by photosynthesis balances CO₂ loss by respiration and net CO₂ is zero. Plants with C₄ metabolism have a CO₂ compensation point of zero or nearly zero (CO₂ compensation point of C₃ plants is 35 – 50 ppm, while for C₄ plants 0 – 10 ppm.)

In C₃ plants additional CO₂ decreases photorespiration by increasing the ratio of CO₂ to O₂ ratio, which leads to faster net photosynthesis.

11.2.3 TEMPERATURE :

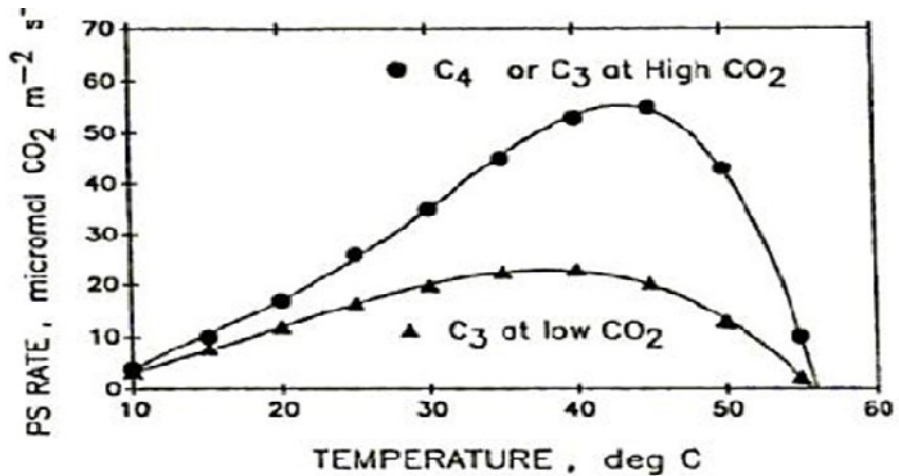
When photosynthetic rates are plotted as a function of temperature, the curves have a characteristic bell shape. The ascending arm of the curve represents a temperature dependent stimulation of photosynthesis up to an optimum, the descending arm associated with deleterious effects.

When photosynthetic rates are measured in air at normal and at high CO₂ concentrations: at high CO₂ there is ample supply of CO₂ at the carboxylation sites and the rate of photosynthesis is limited primarily by biochemical reactions. At ambient (normal) CO₂ concentrations photosynthesis is limited by the activity of RUBISCO.

Temperature rise and CO₂ fixation are conflicting processes. An increase in carboxylation rate with temperature and a decrease in the affinity of the RUBISCO for CO₂ is observed as the temperature rise. These opposite effects slow down the temperature response of Photosynthesis at ambient CO₂ concentrations.

Respiration rates increase as a function of temperature and the interaction between photorespiration and photosynthesis becomes apparent in temperature responses. The quantum yield of photosynthetic carbon fixation in a C₄ plant remains constant with temperature, reflecting typical low rates of photorespiration. In the C₃ plant, the quantum yield decreases sharply with temperature, reflecting stimulation of photorespiration by temperature and an ensuing higher energy demand per net CO₂ fixed.

Optimal temperature is the point at which the capacities of various steps of photosynthesis are optimally balanced. Although there are exceptions, C4 plants generally have higher temperature optima than C3 plants and this difference is controlled largely by lower rates of photorespiration in C4 plants.



TEMPERATURE RESPONSE CURVES

Photosynthetic rate versus temperature for C₃ and C₄ leaves.

11.2.4 Water

When water becomes limiting, cell expansion is first retarded so that growth is reduced. With only a little more water stress, stomata begin to close and CO₂ uptake is restricted. Photosynthesis is then limited by water because of retarded leaf expansion and because of restricted CO₂ absorption.

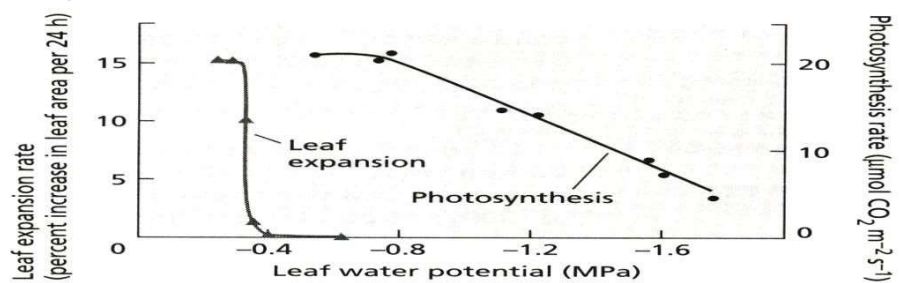


FIGURE Effects of water stress on photosynthesis and leaf expansion of sunflower (*Helianthus annuus*). This species is typical of many plants in which leaf expansion is very sensitive to water stress, and it is completely inhibited under mild stress levels that hardly affect photosynthetic rates. (After Boyer 1970.)

11.2.5 Other factor:

Factors like weedicides, salinity and water logging also affect the rate of photosynthesis. Majority of Herbicides -about half of the commercially important compounds—act by interrupting photosynthetic electron flow.(Ex. Paraquat, diuron). When the electron transport is blocked it virtually stops light reaction of photosynthesis. When light reaction is stopped the dark reaction does not happen and thus CO₂ is not fixed as carbohydrate. Therefore the weed is killed by starvation.
