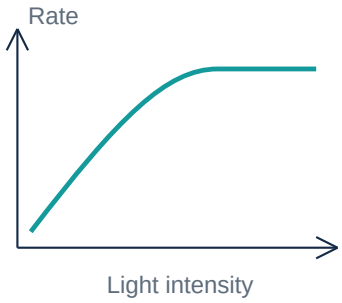
What is restricting the rate?

A limiting factor restricts photosynthesis under the current conditions. Increasing it can raise the rate, until another requirement becomes limiting.

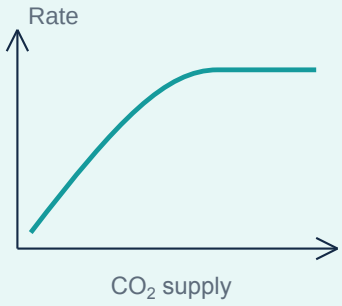
1. LIGHT INTENSITY

Light supplies energy for the light-dependent stage. At low intensity, more light can increase ATP and reduced NADP production. A plateau means additional light alone no longer raises the rate.



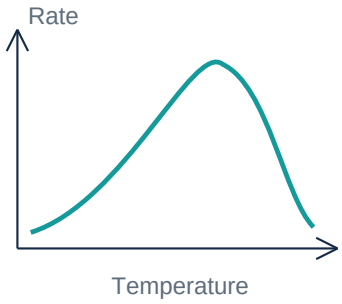
2. CARBON DIOXIDE

Carbon dioxide is a substrate for fixation by rubisco in the Calvin cycle. More CO_2 can raise the rate when carbon supply is limiting, but not indefinitely if light or another requirement limits the process.



3. TEMPERATURE

Enzyme-controlled reactions usually accelerate as temperature rises towards an optimum. Above it, rate can fall because enzymes and membranes are impaired; in whole leaves, stomatal closure may also reduce CO_2 entry.



Curves are schematic, not measured data. Optimum temperature depends on species and conditions. The light and CO_2 curves show the usual rise-to-saturation pattern, not damage at extreme exposures.

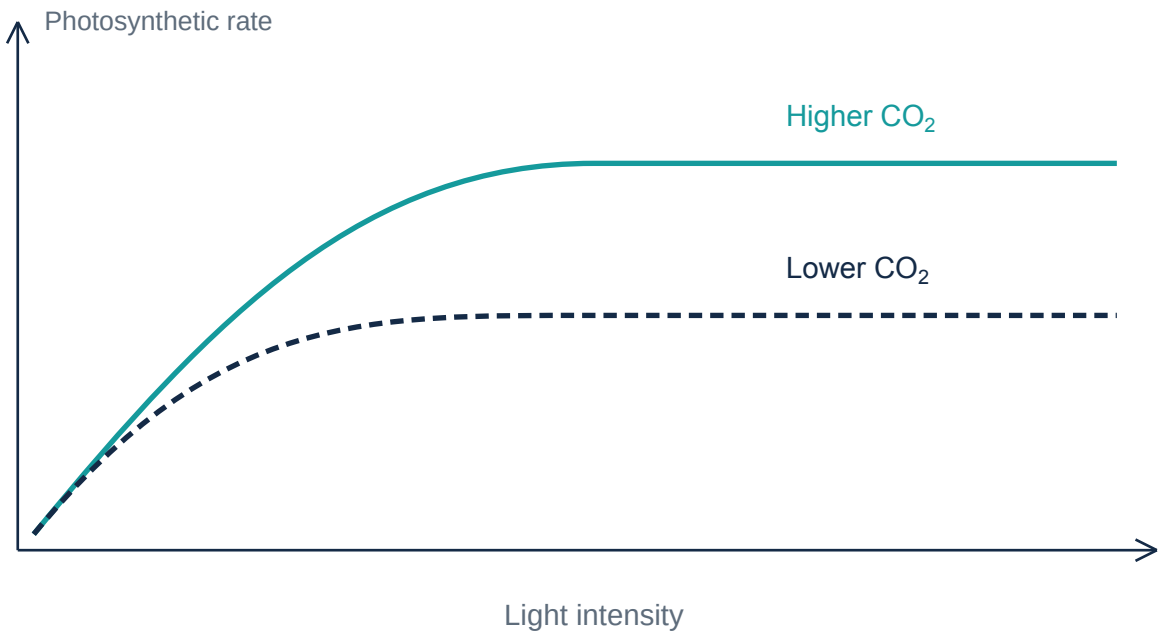
Light and carbon dioxide interactions: Emerson and Green, J. Gen. Physiol. (1937).
Temperature effects: University of Illinois RIPE, photosynthesis and warming.

Scope: Cambridge Biology 9700, section 13.2, outcomes 1-4, p. 36.

Read the response, then test the cause

A plateau shows that increasing the plotted factor has stopped helping. It does not, by itself, identify which other factor is limiting.

1. COMPARE TWO CARBON DIOXIDE LEVELS



Illustrative curves only: same plant material and temperature; different CO_2 supplies.

2. EXPLAIN THE RISING PART

At low light, increasing light intensity raises the rate because light is limiting. Extra carbon dioxide may have little effect while light remains strongly limiting. Compare rates at the same light intensity, not at different x-axis positions.

3. EXPLAIN THE SEPARATION AND PLATEAUS

At high light, a higher rate with extra CO_2 supports carbon dioxide limitation in the lower-CO_2 treatment. To identify a limit at the upper plateau, change another factor while holding the rest constant. Do not simply assume temperature is responsible.

Families of light-response curves: Emerson and Green, J. Gen. Physiol. (1937).
Quantitative investigations: Science & Plants for Schools, A-level practicals.

Scope: Cambridge Biology 9700, section 13.2, outcomes 1-4, p. 36.

Design a fair investigation

Change one independent variable, measure a rate and control the others. Repeat each treatment, calculate a mean and show variation rather than relying on one reading.

1. WHOLE AQUATIC PLANTS

Measure oxygen volume released per unit time, or use an oxygen sensor. Bubble counts are less reliable because bubble size varies and gas can dissolve. Keep species, plant size, temperature and carbon supply constant when changing light. Allow acclimation at each setting; prevent lamp heating with a water bath or heat filter.

2. CHOOSE THE VARIABLE CAREFULLY

Use a light meter at the plant to measure intensity. Change dissolved inorganic carbon supply with controlled hydrogencarbonate solutions, keeping pH in mind; change temperature with a controlled water bath. Keep all non-tested factors constant. Whole-plant oxygen measurements reflect net exchange because respiration also consumes oxygen.

3. ISOLATED CHLOROPLASTS AND DCPIP

Oxidised DCPIP is blue; reduction makes the dye colourless, leaving the chloroplast suspension green. It accepts electrons from the light-dependent reactions. Measure the decrease in absorbance over time, or compare 1/time to a standard colour endpoint using identical starting mixtures. This measures electron-transfer activity, not carbon fixation directly.

4. CONTROLS AND COMPARISONS

Keep chloroplast and indicator concentrations, volumes, pH and temperature constant. Include a dark control and a no-chloroplast control. For wavelength tests, match light intensity across colours. Methylene blue is another redox indicator; do not confuse redox dyes with CO_2/pH indicators.

Whole-plant rate measurements and limitations: Practical Biology.
Chloroplasts, DCPIP and controls: Practical Biology, light-dependent reaction.

Scope: Cambridge Biology 9700, section 13.2, outcomes 1-4, p. 36.