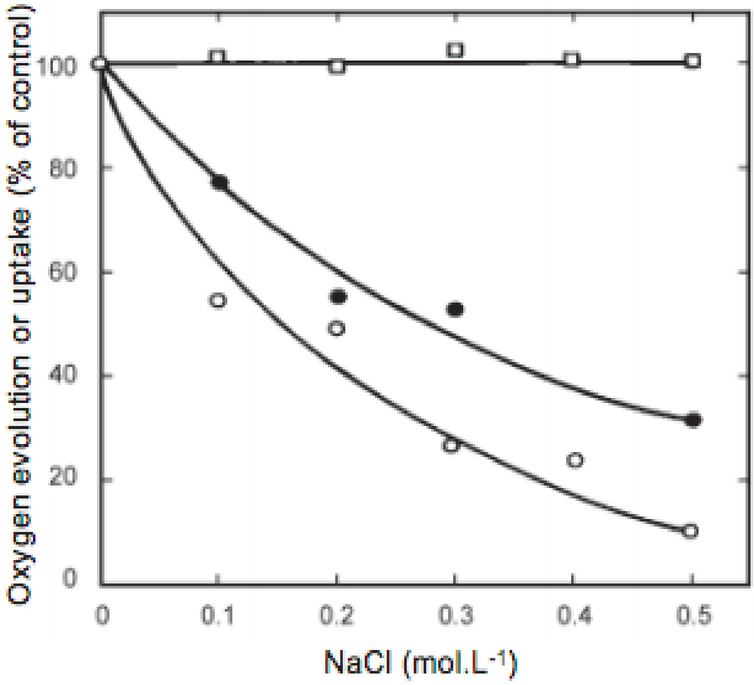
HOW TO USE THIS RESOURCE

Show the figure below to your students along with the caption and background information. The "Interpreting the Graph" and "Discussion Questions" sections provide additional information and suggested questions that you can use to guide a class discussion about the characteristics of the graph and what it shows.



Caption: Increasing salt (NaCl) concentration affects oxygen during photosynthesis by the freshwater alga Chlorella vulgaris*. The three lines represent different parts of the photosynthetic electron transport chain (ETC). Open squares represent photosystem I (PS I). Closed circles represent photosystem II (PS II). Open circles represent the entire photosynthetic ETC, including PS I and PS II.*

BACKGROUND INFORMATION

Increasing salt levels in soil and water can limit the photosynthesis of plants and algae. This can impact the productivity of agricultural crops and of plants and algae in nature. Scientists expect that climate change will cause droughts and sea level rise, both of which could increase salinity in some parts of the world. In particular, sea level rise may upset the salt balance in estuaries, which can impact aquatic plants and algae in those ecosystems.

Previous studies have shown that salt stress reduces photosynthesis in algae, but which part of the process does salt affect? During photosynthesis, water (H_2O) splits to release electrons, oxygen, and hydrogen ions, a process called oxygen evolution. Electrons then move along the photosynthetic electron transport chain (ETC) to produce ATP and NADPH. These molecules are used in the Calvin cycle to create carbohydrates and ultimately more complex molecules. The two light-dependent parts of the ETC are photosystem I (PS I) and photosystem II (PS II).

To investigate how salt affects the ETC, scientists set up a series of experiments to observe different sections of the ETC in isolation. They collected the freshwater alga *Chlorella vulgaris* from the Nile River in Egypt and cultured it in the lab. They designed three separate assays to measure the impact of different salt concentrations on electron flow in the full ETC (specifically, the noncyclic electron flow) and in each of the photosystems (PS I and PS II) individually. The assays for the full ETC and PS II involve measuring the creation, or evolution, of oxygen gas.

The assay for PS I measures the loss, or uptake, of oxygen. The researchers incubated the algae samples in different concentrations of salt (NaCl) for 10 minutes before they took measurements.

INTERPRETING THE GRAPH

The graph shows that the amount of electron transport by PS I did not change across salt concentration. In contrast, electron transport, determined by the assay for oxygen evolution, in PS II and the full ETC decreased dramatically as salt concentration increased. At the highest salt concentration, PS II activity was only 30% that of algae growing without salt stress. In other words, PS II activity was inhibited by 70% at 0.5 mol/L NaCl. This result suggests that salt stress affects photosynthesis at PS II, but not PS I.

Full ETC activity was 90% inhibited by the highest salt concentration. The difference in the degree of inhibition between PS II and the full ETC is not explained by this experiment. Possible explanations are that salt could affect another part of the ETC, or that the experimental isolation of PS II impacted the results.

Teacher Tip: Prompt your students to explain the parts of the graph as applicable:

- Graph Type: Scatter plot with best fit trendlines
- Y-Axis: Oxygen evolution or uptake by *C. vulgaris*, measured as a percentage of oxygen release or uptake by a control *C. vulgaris* culture.
- X-Axis: NaCl concentration (mol·L^{-1}). Note that this is a useful opportunity to remind students about molarity.
- Legend: Open squares represent the activity of PS I, closed circles represent the activity of PS II, and open circles represent the activity of the entire photosynthetic ETC, including both PS I and PS II.

DISCUSSION QUESTIONS

- Describe the differences between the three trendlines.
- Why do you think different parts of the ETC might be affected differently by salt stress?
- Why was it important for the researchers to test each photosystem individually and compare them to the overall output of the entire ETC?
- Calculate the changes in oxygen evolution from 0.0 to 0.5 mol·L^{-1} for each photosystem and the full ETC. How do these changes differ? What does this tell you about the effect of salt stress on photosynthesis? Use evidence from the figure.
- Why do you think that two of the curves in the figure have a similar shape?
- What ideas do you have for the reasons for the difference in oxygen evolution between the two similar curves?
- Using prior knowledge about the photosynthetic electron transport chain, which products of photosynthesis were most likely affected by salt stress in this study?
- Using prior knowledge about the Calvin cycle, which stage(s) of the cycle would be most directly affected by exposure of *C. vulgaris* to increased salinity? Use evidence from the graph to support your prediction. (Note that these two previous questions are most appropriate for higher level students.)
- Which of the following is a good indication that an estuarine system has experienced an abnormal increase in salinity?
  - *C. vulgaris* would increase in number, causing an algal bloom and thereby increasing the populations of species that feed on this alga in the estuary.
  - *C. vulgaris* would decrease in number, reducing the populations of species that feed on this alga.
  - *C. vulgaris* populations would remain steady and, in turn, the populations of species in the estuary would remain stable.

KEY TERMS

estuary, oxygen evolution, photosynthesis, photosynthetic electron transport chain, photosystems I and II, salinity

SOURCE

Figure 1 from:

El-sheekh, Mostafa M. (2004). Inhibition of the water splitting system by sodium chloride stress in the green alga *Chlorella vulgaris*. *Brazilian Journal of Plant Physiology*, 16(1), 25-29.
http://www.scielo.br/scielo.php?script=sci_arttext&pid=s1677-04202004000100004

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