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Interactions of Light, CO_2 and Temperature on Photosynthesis

Light and temperature are two of the most commonly manipulated environmental factors in greenhouse crop production. Supplemental lighting is useful during light-limiting conditions, while during high-light conditions, shading is often used to help prevent excessively high greenhouse temperatures. Often times, we simplistically think about light as the driver of photosynthesis and temperature as the key to control crop timing. Although that's generally true, other cultural and environmental factors influence photosynthesis and thus, crop growth and quality.

Light provides the energy for photosynthetic pigments to convert carbon dioxide (CO_2) and water into sugars and oxygen. As light intensity increases – until a point – the amount of sugars increases and thus, more energy is available for plant growth and maintenance. However, the concentration of CO_2 and temperature also influence photosynthesis in a potentially dramatic way. Cultural factors such as watering and fertility also influence photosynthesis; when these are limiting, photosynthesis is also limited.

Effects of CO_2. The CO_2 concentration outdoors continues to increase and is now 400 ppm — and even higher near urban areas. While this increase has negative effects on the environment, it is a main ingredient for photosynthesis and thus subtly increases plant growth. However, the CO_2 concentration inside a greenhouse is often not at 400 ppm. For example, when greenhouses are closed during the winter and filled with crops, CO_2 is used by plants and the concentration becomes low, perhaps as low as 200 ppm. As Figure 1 illustrates, a low CO_2 concentration has two consequences: photosynthesis is reduced and the light saturation point is decreased. (The light saturation point is the intensity at which additional increases in light do not increase photosynthesis.) This means the value of supplemental lighting is marginalized at a low CO_2 concentration.

Photosynthesis increases as CO_2 increases until some saturating concentration, which is typically around 1,000 ppm. Enriching the air with CO_2 enables plants to more effectively utilize light, resulting in an increase in the light saturation point. Just as with supplemental lighting, the law of diminishing returns applies to CO_2 supplementation. Increasing the CO_2 concentration from 300 to 500 ppm causes a much greater increase in photosynthesis than increasing the CO_2 from 800 to 1,000 ppm. In the United States, few growers of ornamentals use supplemental CO_2, but it is commonly used in greenhouse production of vegetables, especially for tomatoes.

Effects of temperature. The rate of most biological processes increases with temperature and that's also the case with photosynthesis. However, the "optimum" temperature for photosynthesis depends on the concentration of CO_2, as illustrated by Figure 2. When the CO_2 concentration is low, the rate of photosynthesis peaks at a moderate temperature, which varies from one crop to the next. If a greenhouse is enriched with CO_2, then the rate of photosynthesis increases much more dramatically with increases in temperature, resulting in a higher "optimum" temperature for photosynthesis.

To maximize plant responses to light, consider bringing in fresh outdoor air during the day when the greenhouse is closed (during the winter) to avoid CO_2 depletions. In addition, consider the costs/benefits of CO_2 supplementation during periods of limited ventilation, especially when supplemental lighting is used. Remember that the benefits of CO_2 enrichment are greater under high light levels and at warmer temperatures. Finally, during the summer, don't excessively shade plants since that can limit photosynthesis. g

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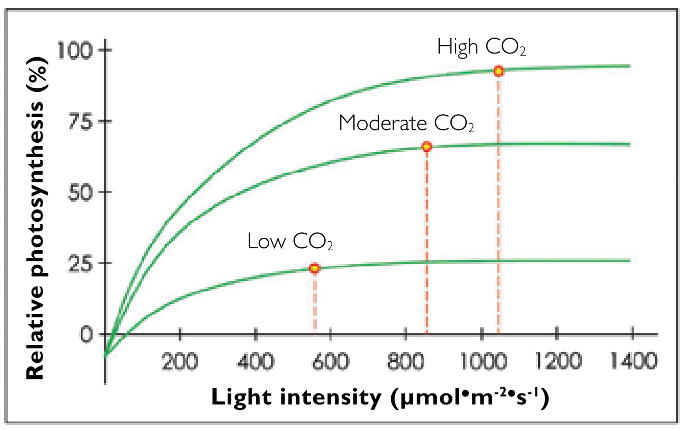

Figure 1 (top). *An illustration of how plants can use more light for photosynthesis when the concentration of carbon dioxide (CO_2) increases. The dots indicate the light saturation points, and above these values, additional light does not increase photosynthesis.*

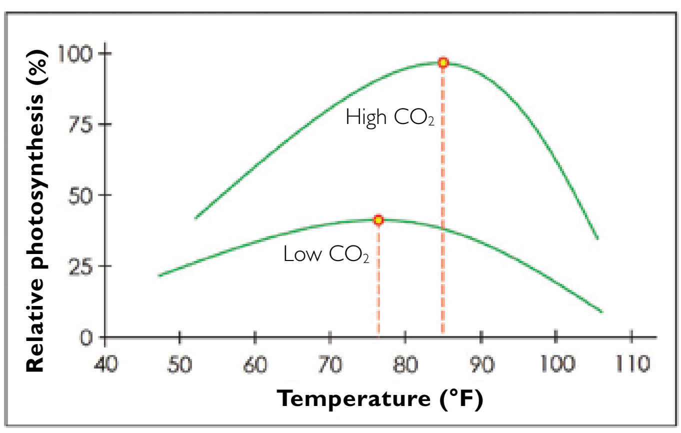

Figure 2 (bottom). *Photosynthesis of many plants increases as both temperature and especially CO_2 increase, until maximum values. These curves illustrate that the temperature for maximum photosynthesis increases when CO_2 is enriched inside a greenhouse.*