Supplemental light and carbon dioxide can improve yield and fruit quality in greenhouse tomato production.

Supplemental lighting may be needed to extend production into the winter months.

Increasing carbon dioxide levels during daylight hours can increase crop yield (biomass production).

**Light**

The amount of available light in a greenhouse affects the ability of a tomato plant to photosynthesize, and that in turn affects the growth characteristics of the plant including fruit development, taste, and quality. Depending on the source of light, the amount of light can also affect the temperature in the greenhouse and plant temperature. Some light sources have associated infrared radiation, which increases the plant temperature even over the greenhouse air temperature.

**High-light conditions** often occur in the summer when intense sunlight is present. The main problem with abundant sunlight in the summer is the associated increase in temperature within the greenhouse, which can cause problems with flower quality and fruit set. The application of whitewash or diffusion coatings to the greenhouse or the use of shade cloth mitigates this issue as they lower the light intensity within the house, reducing the level of solar heating, and decreasing the amount of direct sunlight reaching the plants. The application of whitewash/diffusion coatings or shade cloth can substantially reduce the energy costs associated with cooling greenhouses in the summer or allow vents to remain closed longer, allowing CO₂ levels to increase.

**Low-light conditions** can be problematic in the late fall, winter, and early spring growing periods when the intensity of sunlight is low, and the number of daylight hours are reduced, especially when this coincides with high fruit loads. For tomatoes, low light levels result in plants with longer internodes and less vigorous growth. Flower bud development and fruit set are also reduced in low light conditions. To some extent, cultural practices can be used to help tomato plants adapt to low light levels. Under low light conditions the 24-hour average temperature and the amount of water applied should be reduced.

**Winter production** in northern locations requires the use of supplemental, artificial lighting to obtain acceptable levels of production. The energy costs associated with the use of artificial lighting can be substantial and should be considered when evaluating the economic feasibility of the operation.

Although several types of lighting are available for use in greenhouses, most growers currently use high-pressure sodium (HPS) lamps (Figure 1a). HPS lamps help to provide adequate levels of photosynthetically active radiation (PAR), in other words, the type of light useful for photosynthesis. HPS lamps have an efficiency rating of only about 25%, and they can give off a fair amount of waste heat (both radiation and convection). The waste heat can be helpful in heating greenhouses in the winter. However, heat given off by HPS lamps can burn plant tissues if they are located too close to the plants. The large reflectors used with HPS lamps can also block sunlight during the day. HPS systems can be expensive to operate over the life of the units.

Light emitting diode (LED) lighting (Figure 1b) is becoming more available for greenhouse production systems. One advantage of LED lighting for plant growth is that they emit narrow spectra of light that can be designed to maximize photosynthetic efficiency because there is no wasted light. Plants need light in the photosynthetically active radiation (PAR) region of the light spectrum (400 to 700 nm). The process of photosynthesis uses mostly the blue and red wavelengths, but other wavelengths in the PAR are used for various biological processes of the plant including photoperiod responses and pigment development. Adding a low percentage of white light also makes conditions more comfortable for workers in the greenhouse. Another advantage of LED lighting is that they have much cooler operating temperatures. This allows them to be placed much closer to plants with fewer concerns about burning plant tissues. In fact, some LED lights can be placed within the canopy (inter-canopy lighting) to maximize their efficiency.

Supplemental lighting can induce early fruit production and (Continued on page 2)
increase fruit number and total fruit weight in greenhouse production systems. A study comparing the use of LED and HPS lighting for greenhouse tomato production found that inter-canopy lighting with LED towers was 75% more efficient than overhead HPS lighting. In this study, there were no differences in yield (fruit number or weight) between the two lighting systems, but the cost of the energy with the HPS system over the season was $61.18 per plant, while the cost of energy in the LED system was $14.68 per plant. Intercanopy lighting can also improve fruit/cluster quality.

**Carbon Dioxide**

Plants use carbon dioxide (CO₂), water, and sunlight to produce sugar in the process of photosynthesis. Increasing the CO₂ concentrations above ambient (naturally occurring) levels can improve plant growth, promote earlier flowering, increase the number of flowers, and result in higher yields. On sunny days, increasing the CO₂ concentration to 1,000 ppm can increase the rate of photosynthesis by approximately 50% over the rate at ambient levels (340 ppm). The level of CO₂ can drop to 200 ppm as it is consumed by plants, and the use of supplemental CO₂ is needed to keep the levels in the ambient range or above. Under low-light conditions, the optimal CO₂ concentration is between 400 and 600 ppm. CO₂ applications are most beneficial early and late in the day during daylight hours. For tomato seedlings, CO₂ concentrations of 800 to 1,000 ppm are recommended after seedlings are established when using high quality CO₂. Contaminants in flue gases can damage young plants.

**Sources of CO₂:** There are several ways to supply additional CO₂. One way is to burn carbon-based fuels such as natural gas, propane, and kerosene. The heat produced from burning can be beneficial in the cooler parts of the growing season to help heat the house. In some systems (low to mid-tech houses) the process also produces moisture, which can help keep the humidity levels up during the heating season. However, the extra heat and moisture can be problematic when outside conditions are warm and humid. In addition, incomplete combustion of the fuels or impurities can result in pollutants being released in the house that are toxic to plants causing damage. The air quality in the house should be monitored for carbon monoxide levels to ensure worker safety.

Tanks of liquid CO₂ can be used as sources of CO₂. This method avoids the problems associated with burning fossil fuels (heat, moisture, air pollutants), which eliminates crop damage and worker safety concerns. It is easier to control CO₂ concentrations using liquid CO₂, and the timing of application is more flexible. However, the system setup costs can be higher, and purchasing liquid CO₂ can be expensive.

Decomposing manure or other organic matter release CO₂, and these sources are sometimes used to increase CO₂ levels in organic production systems. The levels of CO₂ released vary with the composition of the organic matter and with microbial activity, so this method is less precise and less controllable than burning fossil fuels or injecting liquid CO₂, and the organic materials typically serve as an effective source of CO₂ for only about a month before needing to be replaced.

**Recommended levels:** A CO₂ controller can be installed in the greenhouse to monitor and adjust CO₂ levels throughout the day. When the greenhouse vents are closed during the day, a CO₂ level of 1,000 ppm is recommended. Light levels also influence the need for added CO₂. The higher level of 1,000 ppm is recommended for sunny days, but 400 ppm of CO₂ is recommended for cloudy days. Excessive levels of CO₂ (above 5,000) should be avoided as they can cause damage to plants, provide no economic benefit, and can be dangerous for people in the greenhouse.

**Application timing:** Elevating CO₂ levels in the greenhouse should begin shortly after sunrise (or turning on supplemental lighting) and end about one hour before sunset. CO₂ is usually only applied during the day, when plants are photosynthesizing. Additional CO₂ at night can be effective if supplemental lighting is being used to extend the period of photosynthesis.

**Distribution:** Good air circulation within the greenhouse will help evenly distribute CO₂ within the house, even when not providing supplemental CO₂. Supplemental CO₂ should be added through a distribution system (piping/hoses) to raise the levels evenly throughout the house (Figure 2).

With fossil fuel burning systems in lower tech houses, the distribution usually occurs well above the plant canopy to prevent heat damage to the plants. In higher tech houses the burning is done off-site and CO₂ is distributed below the crop. With a liquid CO₂ system, emitters also can be placed below the canopy or directly in the lower canopy to provide a more efficient delivery of the CO₂ to the plants.

**Sources:**


Websites verified 10/24/2019

For additional agronomic information, please contact your local seed representative.

**Performance may vary:** from location to location and from year to year, as local growing, soil and weather conditions may vary. Growers should evaluate data from multiple locations and years whenever possible and should consider the impacts of these conditions on the grower’s fields. The recommendations in this article are based upon information obtained from the cited sources and should be used as a quick reference for information about greenhouse tomato production. The content of this article should not be substituted for the professional opinion of a producer, grower, agronomist, pathologist and similar professional dealing with this specific crop.

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