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Year-Round Leafy Greens

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If the water temperature in hydroponic leafy greens production systems is too warm (above the mid-70s) root diseases like Pythium can proliferate more quickly.

Photo credit: Neil Mattson, Cornell University.

Controlled environment growers looking to begin producing food crops usually choose to start with leafy greens. Most leafy greens are relatively short-term crops that can be produced in large quantities.

“Leafy greens are crops considered to be salad components, including lettuces, arugula, bok choy, kale, mustard, mizuna, watercress and spinach,” said Dr. Neil Mattson, professor and greenhouse extension specialist at Cornell University. “These would be crops that form the bulk of salads. The crops could change depending on the season during which they are grown.”

Light intensity

As seasons change, so, too, do the outdoor climate conditions. Neil said leafy greens growers located in northern climates face the challenges of natural low

light levels and cold outdoor temperatures during winter.

“Being in New York, my perspective is more of a northern grower,” he said. “During the winter is when providing supplemental light and operating boilers can allow growers to dial in the environmental conditions necessary to produce leafy greens. If there isn’t an adequate supplemental light capacity, then there is going to be low Daily Light Integrals (DLI), resulting in longer crop times to attain the desired yields.”

Similarly, he said, if temperatures are low, that will also slow plant development and growers will need to decide how much energy they’re willing to use—as well as money they’re willing to spend—to push their crops.

Based on research conducted at Cornell University, the optimum DLI for butterhead lettuce is $17 \text{ mol} \cdot \text{m}^{-2} \cdot \text{d}^{-1}$. If a lettuce crop is pushed too fast or if the light intensity goes too much above that level, then growers can run into issues with calcium deficiency, resulting in tipburn, Neil said, which is often associated with closed head

lettuces or mature heads.

During a typical New York winter, he said high light level days would be 15 moles outside the greenhouse, with about 10 moles transmitted into the greenhouse.

“The worst winter days for light intensity under cloudy conditions are about 1 to 2 moles,” he said. “On very cloudy days, the sun supplies about 5% to 10% of the light needed by the plants. Under these low light conditions, 10 to 12 moles is the minimum light level necessary. If minimum light levels are not maintained, plants grow very slowly and will stretch and elongate so the quality is very poor.”

Conversely, he said the biggest concern with high light intensities are greenhouses overheating, requiring growers to provide some type of shade.

Preventing tipburn

Because tipburn is associated with higher outdoor light levels, the summer is when the disorder occurs most often.

“Another time that tipburn occurs more frequently is during the shoulder season of spring transitioning into summer,” Neil added. “At this time growers haven’t updated the amount of shade they have applied to the outside of the greenhouses or they don’t pull shade cloth to accommodate the increase in natural light levels. The first or second crop cycle during the spring-to-summer transition is when most tipburn occurs. Growers realize they need to apply a shade compound or retractable shade curtains need to be programmed to close more quickly during the day.”

Summer can see days with upwards of 60 moles of light outside and 40 moles entering the greenhouse, making the environment too hot. That can result in major tipburn, as well as premature bolting issues, he said. “If the greenhouse is equipped with a 50% shade curtain that can be deployed on these high light days, the light level can be reduced to 20 moles on the crop.”

Karla Garcia, technical service at Hort Americas and CEO at Microgreens FLN, said tipburn triggered by high light levels is mostly relevant to indoor production, such as vertical farm systems or plant factories.

“In plant factories, the recommended DLI for lettuce is typically capped at around 17 moles,” she said. “In contrast, greenhouse-grown lettuce can tolerate much higher light levels without showing tipburn. This difference is due to the way plants interact with the surrounding environment in each system.”

Although tipburn can occur during the summer and winter, it’s much more common under high temperatures and high humidity.

“This is usually because the temperature is going up in the greenhouse, plants are stressed more and airflow may not be good enough,” Karla said. “This will cause the humidity to increase, leading to calcium deficiency.”

She recommended checking the environment before adding nutrients. “Some growers will try to fix a tipburn



Although tipburn can occur during both the summer and winter, it’s much more common under high temperatures and high humidity.

Photo credit: Karla Garcia, Hort Americas.

problem with foliar calcium sprays,” she explained. “These applications will work because calcium is being provided directly to the leaves, but this is not resolving the source of the problem. It’s better to fix the environment.”

Neil said some automated controlled environment growers are harvesting their lettuce crops earlier, which is referred to as the “teen” leaf stage (between baby leaf and mature head lettuce).



During the winter, leafy greens growers typically provide supplemental light to ensure plants receive an adequate Daily Light Integral (DLI) to prevent longer crop times and produce the desired yields.

Photo credit: Neil Mattson, Cornell University.

“These teen leaf salad mixes are becoming increasingly popular in operations equipped with mobile gutters that move through the greenhouses,” he said. “Plants are seeded at a higher density in a growing substrate in a gutter. These crops are harvested after 25 days instead of 35 days for head lettuce. Teen leaf lettuces can be pushed faster with a higher DLI of 20 to 24 moles.

“Teen leaf lettuces are not as sensitive to tipburn. Lettuce heads tend to be more sensitive to tipburn at the end of their growth cycle when there is a compact head with the outer leaves wrapping around the inner leaves. There is an inhibition of transpiration of the plants.”

Temperature, humidity

Warmer temperatures in the greenhouse can result in an increase in the relative humidity. Karla noted when the humidity starts to increase there can be issues with condensation, which can also release heat in the greenhouse. She said growers need to pay attention to the humidity and try to maximize ventilation to lower the humidity and reduce an increase in temperature.

“Higher humidity can lead to issues with pathogens, including fungi and bacteria to develop,” she added. “If there isn’t adequate airflow inside the greenhouse, there can be issues with the movement of some nutrients, including calcium, which can result in tipburn.”

Neil said leafy greens growers should maintain a greenhouse temperature of 74F (23C) during the day, with temperatures going no higher than 80F (26C). At night the temperature should be 68F (20C).

“Growers have to decide how much fuel they want to use to achieve faster growth rates,” he said. “Lettuce and some other leafy greens can tolerate cooler temperatures, but they’ll grow slower and produce lower yields.”

During the shoulder seasons, temperatures aren’t usually as extreme as during the summer and winter. Those hot, sunny days can also be humid, and if a greenhouse’s temperature is in the mid to upper 80s for multiple days in a row, it can cause earlier bolting in lettuce, arugula and spinach, Neil said. The plants will start to flower or go to seed too quickly.

“Instead of producing a nice, compact head or compact growth form, the plants will stretch,” Neil added. “If plants are allowed to bolt, they become unmarketable. The stems and leaves also become bitter tasting.”

Water temperature, oxygen level

Water temperature can impact leafy greens growth and susceptibility to disease, which can change according to seasons.

“Municipal water during winter might be colder than it is during the summer,” Neil noted. “If this cold water is being used in a hydroponic system like nutrient film technique (NFT) channels or troughs or in deep water culture (DWC), cold water can inhibit root growth and root respiration, slowing down plant growth.”

Some deep water culture growers will heat the water so that it's closer to the root temperature (70 to 74F) before the water is added to the ponds. Neil said for NFT systems there's more surface area in a trough and less insulation than DWC, adding if the water is run through the production system even for a few hours, it's going to heat up relatively quickly to the air temperature. A bigger concern during summer is when the greenhouse air temperature is warmer than optimum.

“If the ideal production temperature is 74F, but realistically the greenhouse air temperature is averaging 78 to 82F, the water temperature, especially in NFT systems, is going to rise relatively quickly to the air temperature,” Neil said. “The water temperature will track the air temperature in the greenhouse with only a bit of a delay.

“Similarly, pond water in deep water culture will take longer to reach the air temperature because there is a bigger buffer with the large volume of water making it more insulated. Eventually, over a course of several days, the water in the pond will warm up to the average air temperature.”

If the water temperature is too warm, above the mid-70s, the main concern is root diseases, which can proliferate more quickly. Neil said these pathogens can complete their life cycles more quickly in warm water.

“Hot water holds less dissolved oxygen. Roots need dissolved oxygen to respire and grow,” he explained. “There is less buffering capacity because there is less oxygen in the water at warm temperatures.”

Regardless of the time of the year, Neil said growers are using some methods to keep dissolved oxygen levels high in the water. This can be done by adding oxygen directly to the water using tanks of liquid oxygen. Air can also be pumped into deep water ponds by using air stones or Venturi pumps. With NFT systems, the mechanical movement of the water allows for exchange of the air that oxygenates the water.

“In summer when the water temperature is hot, the maximum amount of dissolved oxygen the water can hold goes down,” he said. “It becomes more difficult to maintain the oxygen level that can max out at 6 to 7 ppm oxygen rather than 8 to 9 ppm.”

Karla said when using traditional deep water culture, the target oxygen level should be 6 to 9 ppm. “For leafy greens, 9 ppm oxygen is good, 11 ppm is better,” she said. “There are some oxygen generation systems available where the oxygen level can be as high as 20 to 30 ppm. These systems could be used in production locations with very warm temperatures.

“Leafy greens have a very sensitive root zone. Warm temperatures can affect a crop, but if there is good oxygenation of the root zone, that can compensate for the warm temperatures.” **IG**

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