CULINARY HERBS:
Balancing Light and Average Daily Temperature

In this fourth article in a five part series on potted and hydroponic culinary herb research at Michigan State University (MSU), we will show you how temperature and light interact to influence herb growth, development, and foliage color.

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Often as researchers we are asked what light intensity or temperature is recommended for greenhouse culinary herbs, and often we reply with, "it depends."

And it does! The answer to that depends on many other factors. What is most important to your bottom line and customers: yield, flavor, color, leaf size, or postharvest life? These questions led us to begin to develop temperature and light models to serve as decision support tools for herb growers.

Temperature fundamentals

Let's first talk about the basics of plant responses to temperature. Plant development, including the rate of leaf unfolding, is primarily a function of temperature integrated over time or the average daily temperature (ADT).

A temperature response curve can be used to describe this relationship. Below the base temperature (T_b), the rate of development ceases. As temperature increases above the T_b, the rate of development increases, usually linearly, until the optimum temperature (T_{opt}) is reached. T_{opt} is the temperature at which development rate is the greatest. Beyond T_{opt}, the rate of development decreases until the maximum temperature (T_{max}), above which it ceases.

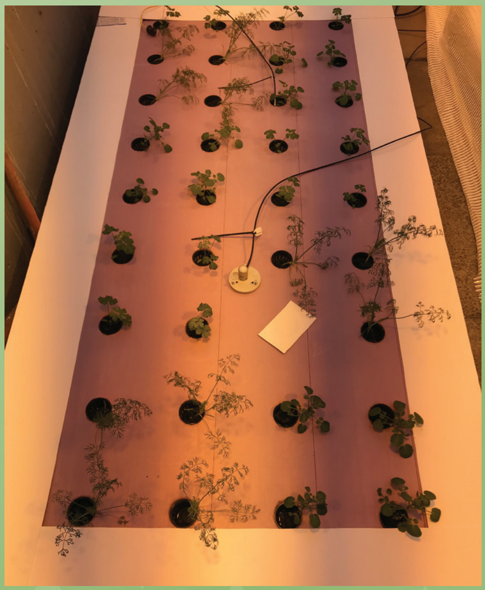

Fig. 1. Deep-flow hydroponic tanks containing dill and watercress.

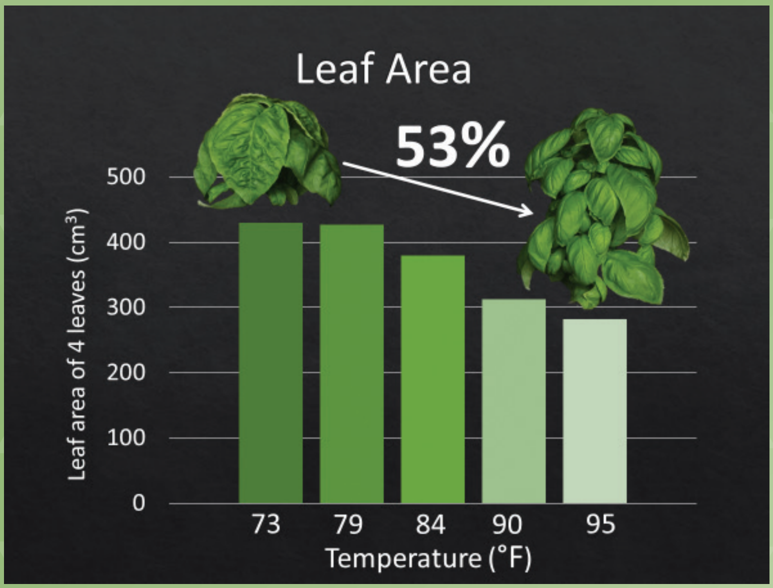

Fig. 2. Increase in leaf area after transplant of sweet basil 'Nufar' with target average daily temperatures of 73, 79, 84, 90, or 95°F.

Light is essential to plant growth as it drives photosynthesis. In this case, we are interested in the total amount of light over the course of the day or the daily light integral (DLI). In general, increasing DLI to a certain point increases growth, quality, and yield. However, the benefit of added light can depend on other environmental factors, including temperature and carbon dioxide concentration.

Production

In this study, we grew dill 'Bouquet', parsley 'Giant of Italy', purple basil 'Dark Opal', sweet basil 'Nufar', sage 'Extrakta', spearmint 'Spanish', and watercress. Cuttings and seeds were stuck and sown in 200-cell rockwool cubes and placed in a greenhouse and grown at 73°F until transplant.

After two (sweet basil and spearmint), three (purple basil and watercress), four (dill and sage), or five (parsley) weeks, the seedlings and liners were transplanted into deep-flow hydroponic systems (**Fig. 1**) and grown in five greenhouse compartments with ADTs ranging from 49°Fto 81°F (dill, parsley, and watercress) and 73°F to 96°F (purple basil, sage, and spearmint). The plants were grown under 0%, 30%, or 50% shade cloth and supplemental lighting to create DLIs ranging from ~6 to 18 $mol{\cdot}m^{-2}{\cdot}d^{-1}$.

Leaf area and number

Sweet and purple basil, sage, and spearmint grown at higher temperatures had smaller leaves. For example, sweet basil 'Nufar' grown at 95°F had leaves about half the size of plants grown at 73°F (**Fig. 2**). The DLI, on the other hand, did not influence leaf size. We accessed leaf number at one point in time, so as temperature increased from ~49°F to 81°F, dill and parsley had 6 more leaves over the 3-week and 4-week growing period, respectively (**Fig. 3**).

Fresh mass

Within our experimental range, increasing DLI increased dill, purple and sweet basil, sage, and spearmint fresh mass with the exception of sage at high temperatures and dill at very low temperature near its T_b. Within our experimental range, DLI did not influence the fresh mass of parsley or watercress.

Dill, parsley, and watercress

Where is the linear range of these crops between their T_b and T_{opt}? As ADT increased from ~50 to 73°F fresh mass of parsley increased by 45 g (**Fig. 4**). As temperature increased to 81°F, fresh mass of dill increased from 39 to 50 g (**Fig. 5**) and watercress increased 20 g. The extent by which temperature influenced the fresh mass of dill depended on the DLI. For example, when the DLI was 6 $mol{\cdot}m^{-2}{\cdot}d^{-1}$ increasing the ADT to 81°F increased mass by 39 g. When the DLI was higher (14 $mol{\cdot}m^{-2}{\cdot}d^{-1}$) the same increase in ADT, increased fresh mass 50 g.

Sage

For sage, when the DLI is 6 $mol{\cdot}m^{-2}{\cdot}d^{-1}$, T_{opt} was 82°F. When the DLI was 18 $mol{\cdot}m^{-2}{\cdot}d^{-1}$, T_{opt} was 74°F. Above this ADT, biomass accumulation began to decrease. While temperature has some effect on fresh mass, the best strategy to increase sage mass is to increase the DLI. For example, our model predicts that at an ADT of 74°F, increasing the DLI from 6 to 18 $mol{\cdot}m^{-2}{\cdot}d^{-1}$ will result in an increase in fresh mass from 32 to 56 g.

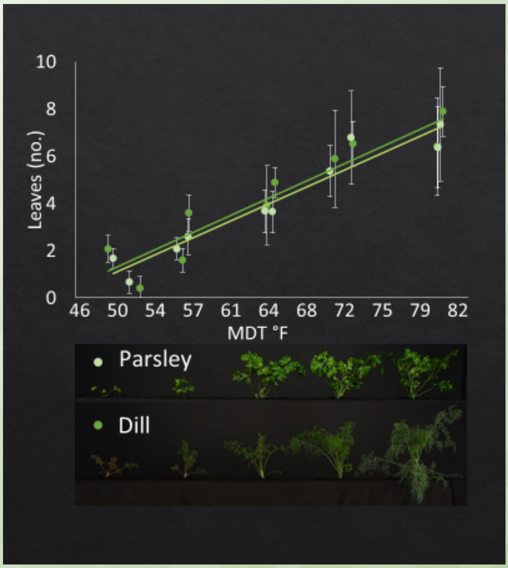

Fig. 3. The increase in leaf number after transplant of dill and parsley plants grown with target average daily temperatures of 52, 59, 66, 73, or 81°F for 3 (dill) or 4 weeks (parsley) after transplant.

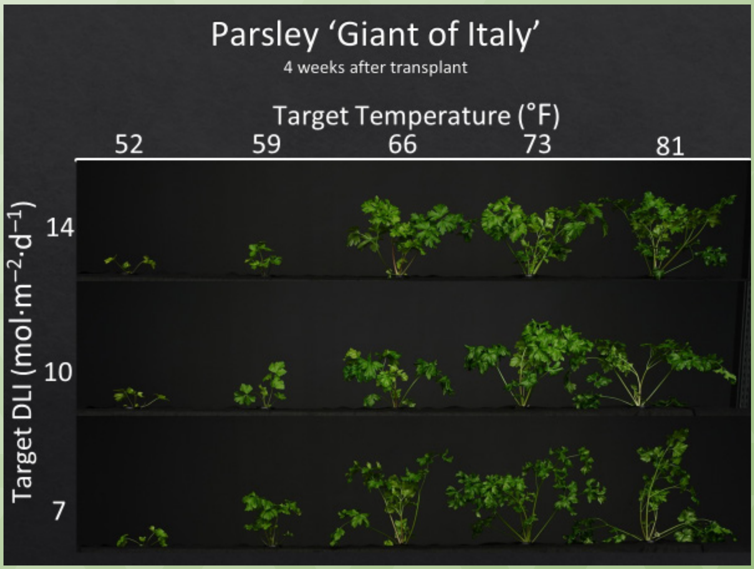

Fig. 4. Parsley plants grown under target daily light integrals (DLIs) of 7, 10, or 14 mol·m^{-2}·d^{-1} and target average daily temperatures of 52, 59, 66, 73, or 81°F. Picture was taken 4 weeks after transplant.

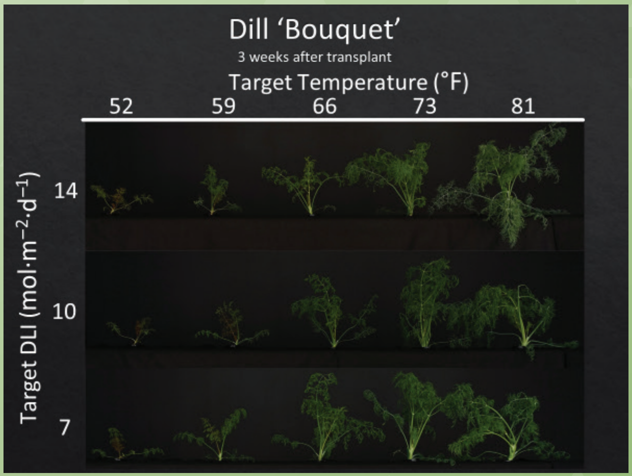

Fig. 5. Dill plants grown under target daily light integrals (DLIs) of 7, 10, or 14 mol·m^{-2}·d^{-1} and target average daily temperatures of 52, 59, 66, 73, or 81°F. Picture was taken 3 weeks after transplant.

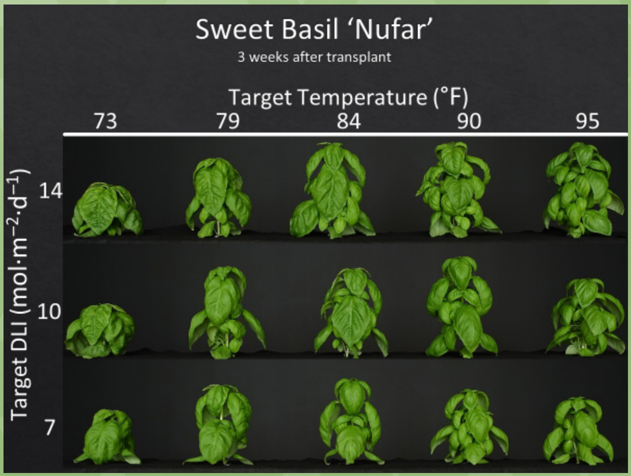

Fig. 6. Basil plants grown under target daily light integrals (DLIs) of 7, 10, or 14 mol·m^{-2}·d^{-1} and target average daily temperatures of 73, 79, 84, 90, or 95°F. Picture was taken 3 weeks after transplant.

Spearmint

For spearmint, the T_{opt} was 87°F when the DLI was 6 mol·m^{-2}·d^{-1}, and 82 °F when the DLI was 18 mol·m^{-2}·d^{-1}. Beyond the T_{opt}, fresh mass was reduced and was more pronounced when the DLI was high. Therefore, if the ADT is high (95°F) and you cannot cool the growing environment, lowering the DLI can help increase fresh mass and thus harvestable yield. However, if the ADT is low (73°F) increasing the DLI will not result in large increases in fresh mass.

Sweet basil

The T_{opt} for fresh mass of sweet basil had the opposite trend than sage and spearmint. When the DLI was 6 mol·m^{-2}·d^{-1}, T_{opt} was 91°F; when the DLI was 11 mol·m^{-2}·d^{-1}, T_{opt} was 96°F (**Fig. 6**). From our research and that of others, we also know that fresh mass of sweet basil can increase as DLI increases much beyond

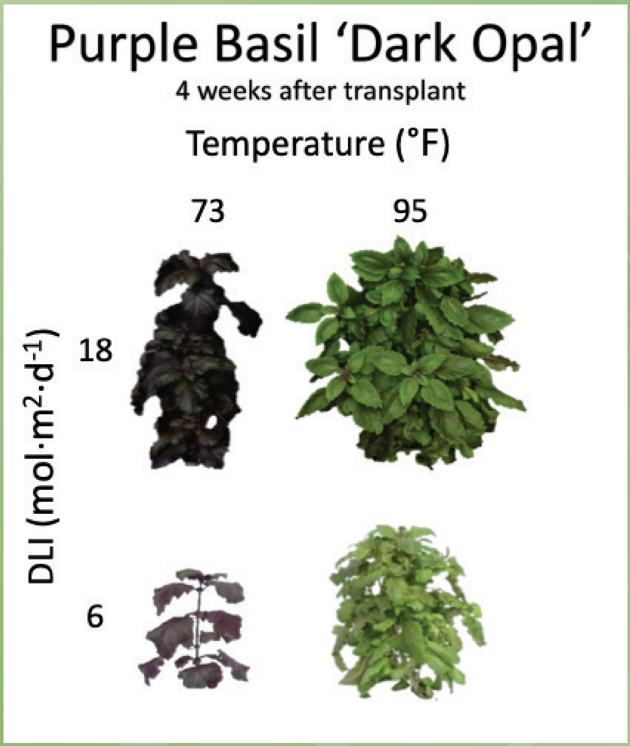

Fig. 7. Purple basil 'Dark Opal' grown with target average daily temperatures of 73°F or 95°F under daily light integrals (DLIs) of 6 or 18 mol·m^{-2}·d^{-1}.

11 mol·m^{-2}·d^{-1} (up to 35 mol·m^{-2}·d^{-1} in some cases).

Purple basil

Increasing the ADT up to 95°F when the DLI is low (6 mol·m^{-2}·d^{-1}), and 90 °F when the DLI is high (18 mol·m^{-2}·d^{-1}) will increase fresh mass.

However, altering the growing environment not only influences mass, but also the color of leaves. For purple basil, color is an additional quality parameter to consider in addition to fresh mass. Purple coloration not only adds to visual appeal but is also an indicator of the concentration of anthocyanin, an antioxidant. At lower temperatures (73°F), purple basil is purple (**Fig.** 7). Increasing the DLI from 6 to 18 mol·m^{-2}·d^{-1}, for example, will not only increase fresh mass, but will also deepen the purple coloration.

While increasing temperature up to 90°F to 95°F increases mass, it also causes the plants to turn green instead of a consistent purple. Our recommendation to increase purple basil yield and color is to increase the DLI, rather than increasing temperature. If yield is more important than color, a green cultivar should be used as green cultivars generally have higher yields than purple cultivars.

The bottom line

Going back to our first question of what the ADT or DLI set-points for culinary herb production should be, after all of our evaluations the answer remains, "it depends." We hope that the insights gained from this research will serve as a decision support tool for improving productivity and resource use for a variety of herbs. Additionally, the model equations generated from this research will be shared broadly once the research is published in scientific journals. **pg**

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