Managing Air Temperature for SPECIALTY Leafy Greens

How can you use temperature to control crop yields and maintain efficient production?

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Greenhouse and controlled-environment production of food crops is increasingly popular among consumers. Specifically, specialty leafy greens including arugula (*Eruca sativa*), kale (*Brassica oleracea*), pac choi (*Brassica rapa var. chinensis*) and Swiss chard (*Beta vulgaris*) are becoming more popular greens for producing hydroponically in greenhouses and other controlled environments.

For consumers, the health-promoting benefits and unique culinary uses for specialty greens make them attractive. For commercial producers, specialty greens can be a desirable crop compared to fruiting vine crops due to their short production time and no specialized infrastructure is required. Greenhouse and controlled-environment crop production is most efficient when producers create environments and use cultural practices that maximize yields for the crops they are growing.

While several factors affect crop growth and development, air temperature has one of the pronounced effects. The rate of development, whether it is leaf unfolding or fresh weight accumulation, is directly related to the average daily temperature (Figure 1). The base temperature (T_{base}) is the temperature at or below which plant development stops, while the maximum temperature is the temperature at or above which development stops. Between T_{base} and T_{max} is the optimal temperature (T_{opt}), the temperature where the rate of plant development is the

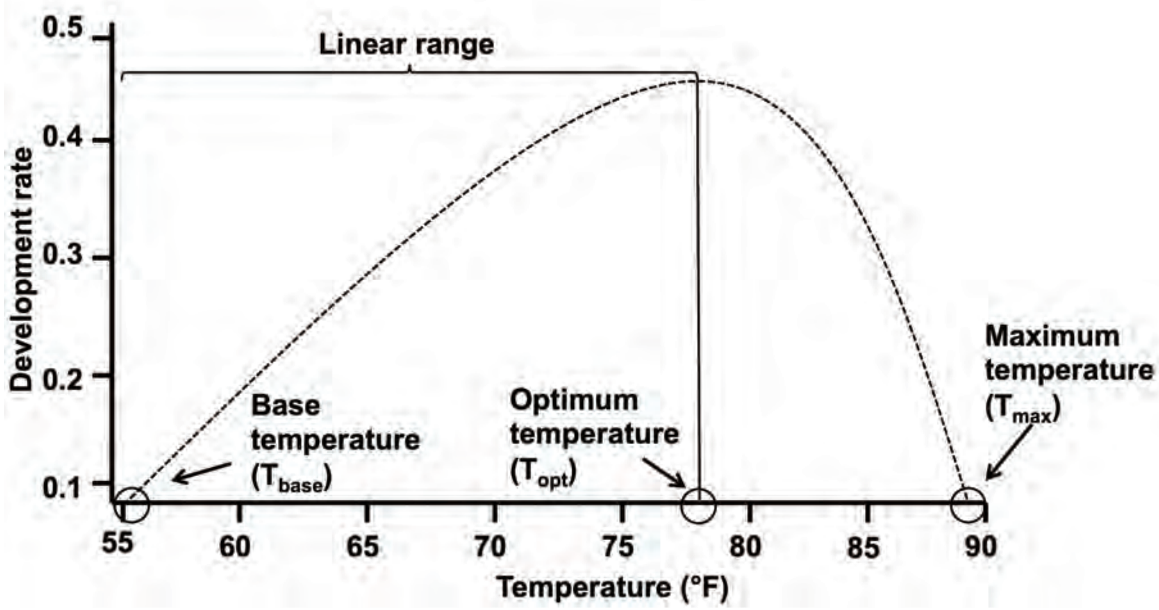

Figure 1. This non-linear, asymmetrical curve represents the generalized response of plant development to air temperature. Cardinal temperatures include the base (T_{base}), optimal (T_{opt}) and maximum (T_{max}) temperatures, and the linear range is between T_{base} and T_{opt}.

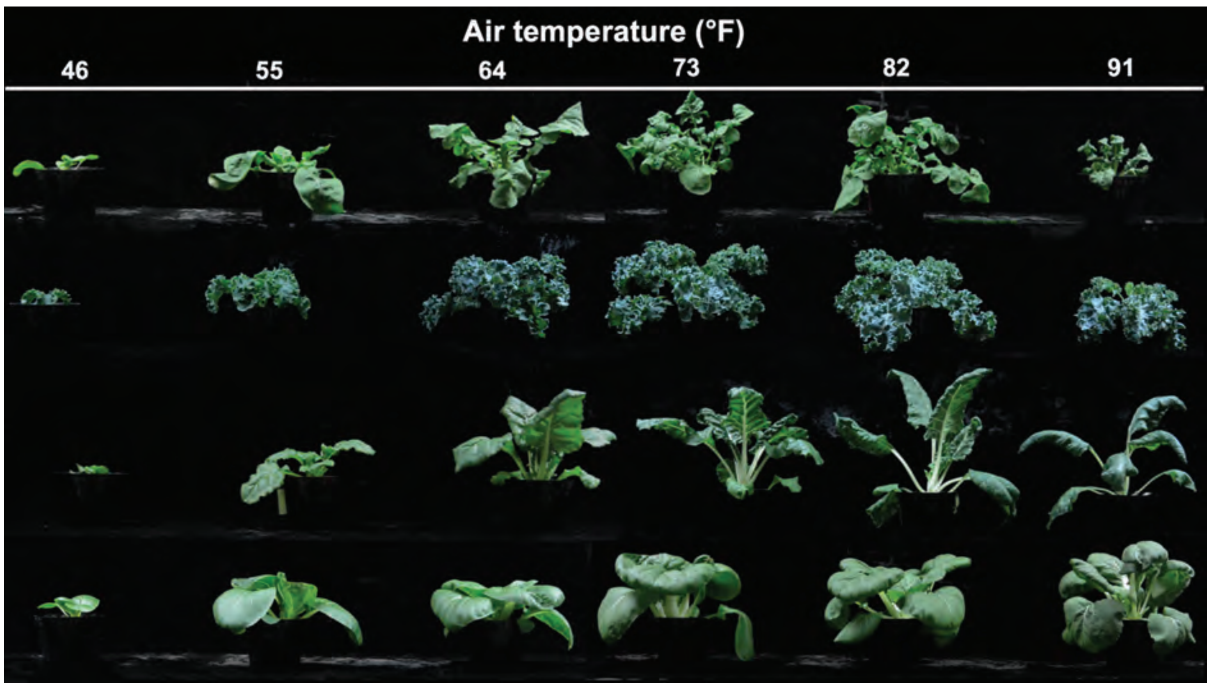

Figure 2. Arugula, kale, pac choi and Swiss chard three (arugula and pac choi) or four weeks (swiss chard and kale) after growing in environmental growth chambers maintained at 46, 55, 64, 73, 82 or 91° F.

greatest. In between the T_{base} and T_{opt} is linear range, where plant development increases or decreases linearly as temperature increases or decreases, respectively. The actual air temperature for these important, or cardinal, temperatures are species-specific, varying with each crop.

Although specialty greens are increasingly popular, there is little information on the environmental and cultural requirements for these species, including their responses to air temperature. We conducted research to quantify the response of arugula, kale, pac choi and Swiss chard to air temperature and determine their cardinal temperatures.

THE EXPERIMENT

Arugula, 'Starbor' kale, 'Win-Win' pac choi and 'Fordhook Giant' swiss chard were sown in 162-cell phenolic foam propagation sheets with a top groove (Oasis HortiCubes XL; Smithers-Oasis) placed in 1020 flats with drainage holes. Immediately after seeding and every day throughout the experiment, flats were irrigated 100-ppm nitrogen from a complete, balanced, water-soluble hydroponic fertilizer (Jack's Hydro FeED 16N-4P-17K; J.R. Peters). Seedlings were grown inside an environmental growth chamber at a constant air temperature of 72° F and a 16-hour day with a photosynthetic daily light integral (DLI) of 14 $mol{\cdot}m^{-2}{\cdot}d^{-1}$.

Two weeks after sowing seed, seedlings were transplanted into 5.5-inch containers filled with a commercial soilless peat and perlite substrate and irrigated with 150-ppm nitrogen from a nitrate-based fertilizer (15-5-15; Peters Excel). After watering plants in with fertilizer, they were placed back into one of six different environmental growth chambers maintained at one of six different constant air temperatures: 46, 55, 64, 73, 82 or 91° F. The DLI was again maintained at 14 $mol{\cdot}m^{-2}{\cdot}d^{-1}$.

Three weeks (arugula and pac choi) or four weeks (Swiss chard and kale) after placing plants into temperature treatments, data were collected. Prior to destructive harvesting, gas exchange (photosynthesis, conductance and transpiration), chlorophyll fluorescence (a measure of stress), and relative chlorophyll concentration were measured, as were plant height and width.

Shoots were harvested and immediately weighed to determine fresh shoot weight (yield), after which time the number of unfolded leaves were counted and the leaf area measured. Shoots were then dried and the dry weight was recorded after three days. To determine the air temperatures corresponding to T_{base}, T_{opt}, T_{max}, and the linear range, data were analyzed using non-linear regression analyses, and these models were used to identify cardinal temperatures for each species.

THE RESULTS

The vast majority of arugula, kale, pac choi and swiss chard responses (Figure 2) displayed the general non-linear, asymmetric response to air temperature demonstrated in Fig. 1. However, the specific air temperatures corresponding to T_{base}, T_{opt}, and T_{max} differed for each species and the responses. For example, the T_{opt} for photosynthesis for arugula and kale were 61.9 and 60.4° F, respectively, while for total leaf area the T_{opt} were 72.1 and 75.7° F, respectively.

For commercial greenhouse and controlled environment food crop producers, yield is the most important aspect of production. For specialty leafy greens, that is the leaf fresh weight (we included stems in measurements for arugula, pac choi and Swiss chard, but not for kale), and while each species will have a number of different cardinal temperatures, we think the T_{opt} for fresh weight are the most useful to base management air temperature management decisions off of.

Based on the models generated from our results, the T_{opt} for fresh mass, where production was greatest, is at 74.8, 77.4, 79.2 and 79.9° F for arugula, pac choi, kale, and Swiss chard, respectively. It is interesting to note these T_{opt} for fresh weight compared were higher than those for photosynthesis for all species. However, even if photosynthesis decreases as temperatures increase above T_{opt}, the leaf area continues to expand and leads to a net increase in photosynthesis when the entire canopy

MANAGING AIR TEMPERATURE

Traditionally, cool air temperatures (~60 to 64° F) have been recommended for these species. Our research certainly supports that these species all can grow at cooler temperatures due to their low temperature tolerance. However, the results of this work also show that these species can grow at air temperatures warmer than these traditionally recommended cooler temperatures based on the T_{opt} for fresh mass. By using warmer temperatures than traditional cool temperature recommendations, specialty leafy greens can be finished more quickly and increases productivity by allowing for more crop cycles.

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It is common for leafy green growers to have several different species in production, and when a number of different species is grown, grouping crops in different sections based on air temperature requirements is an effective strategy for temperature management. Again, arugula, kale, pac choi and Swiss chard can all be grouped with cool-growing crops based on their cold-temperature tolerance. However, they can and should be grouped with other crops that are ures, since arugula, kale, pac choi and Swiss chard will all be more productive, with respect to yields, when grown in the upper 60s and low- to mid-70s.

TAKE HOME

Air temperatures have a strong influence on the rate of plant specialty green growth and development. Arugula, kale, pac choi and Swiss chard have been traditionally considered cool-growing crops. However, our research demonstrates these species can all be grown at warmer temperatures, which can increase yields and the bottom line. gpn

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