

Indoor Production of Herb Seedlings: Light Intensity & Carbon Dioxide

By Kellie J. Walters and Roberto G. Lopez

In this second article of our five-part series on culinary herb research at Michigan State University (MSU), we will highlight the results of pushing the lighting and carbon dioxide envelope during the production of dill, parsley, and sage seedlings indoors without sunlight. To see part one, visit bit.ly/HerbCuttings.

Increasing light intensity up to a certain species-specific point increases the yield (ex. fresh mass) and quality of many crops including culinary herbs. However, what if adding supplemental lighting in the greenhouse or increasing the intensity of sole-source lighting in indoor (vertical farms, warehouses and containers) production for the entire crop production duration is not economically feasible? Dynamic environmental control, or adjusting the growing environment based on plant age or production stage, could be more efficient in enhancing crop yield and quality and reducing production costs.

With more expensive capital and operating costs for indoor specialty crop production, short duration and high-density crops are potentially higher-profit options. With this higher cost of production comes increased environmental control capabilities, including the ability to manipulate sole-source light intensity and quality, temperature, humidity, and carbon dioxide (CO_2) concentration. The question is, how do we leverage this control effectively?

In this study, we focus on indoor herb young plant production, from seed sowing to transplant. Our hypothesis was that increasing production inputs such as light and CO_2 during the young plant stage could give those plants a head start for the finishing stages. Additionally, during young plant production, plant density is much higher than during finished production. For example, a 200-cell tray of culinary herb seedlings can be produced in two weeks in the same area that three to 20 plants

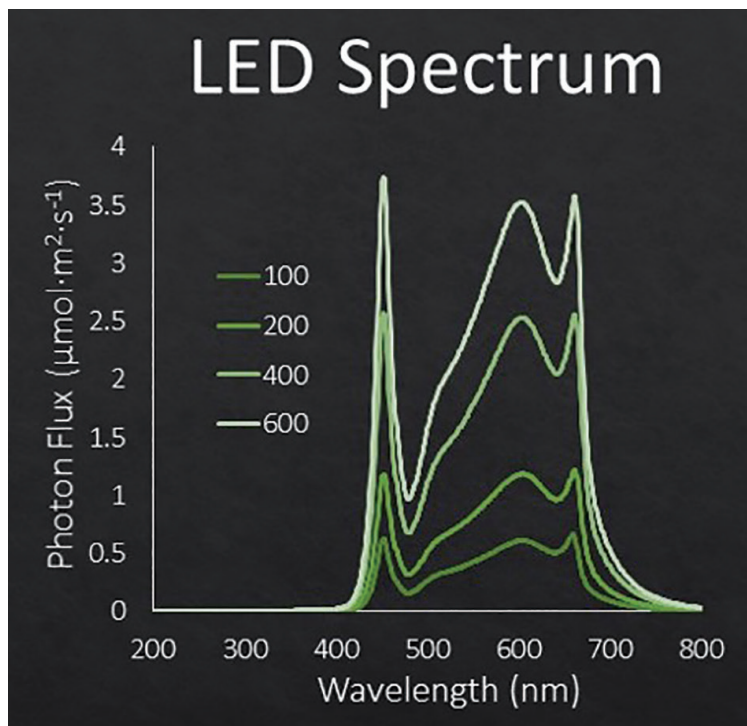


Figure 1. The spectral distribution of Fluence Ray 66 PhysioSpec Indoor LEDs providing a light ratio (%) of 19:39:39:3 blue:green:red:far-red and target light intensities of 100, 200, 400, and 600 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$.

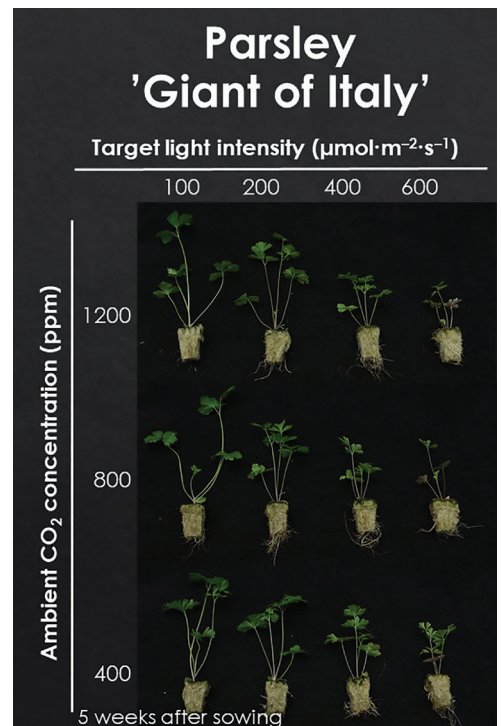


Figure 2. Parsley seedlings grown under light intensities of 100, 200, 400, and 600 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ and CO_2 concentrations of 400, 800, and 1200 ppm. Picture was taken 5 weeks after sowing.

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Sage 'Extrakta'

PRODUCTION

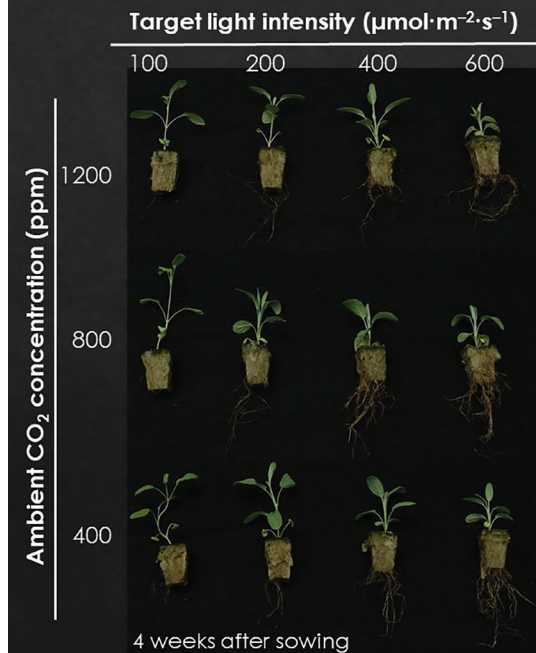


Figure 3. Sage seedlings grown under light intensities of 100, 200, 400, and 600 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ and CO₂ concentrations of 400, 800, and 1200 ppm. Picture was taken four weeks after sowing.

can be grown during finishing stages and harvested in three weeks. If the higher operating and capital cost of indoor production can be spread across a larger number of plants with a shorter production duration, the cost per plant is much less.

In our previous indoor seedling production research focused on basil, we determined that seedling fresh mass was 284% greater when grown under 600 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ (daily light integral [DLI] of 35 $\text{mol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$) compared to 100 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ (DLI of 6 $\text{mol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$). However, increasing CO₂ concentration did not increase fresh mass of basil seedlings. More importantly, after being transplanted into a common greenhouse environment, an 80% increase in fresh mass persisted through harvest. This was a large increase in harvestable yield and we wanted to determine if other commonly grown culinary herbs would have a similar response.

Seedling production

We selected three popular culinary herbs, dill 'Bouquet', parsley 'Giant of Italy', and Sage 'Extrakta.' Seeds were sown in 200-cell rockwool cubes and placed in walk-in growth rooms with CO₂ concentrations of 400, 800 or 1200 ppm. Each chamber was equipped with light-emitting diodes (LEDs) that provided four different light intensities of 100, 200, 400, and 600 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ (Fig. 1). The LEDs were on 16 hours each day to create DLIs of 6, 12, 24 and

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HERBS

35 mol·m⁻²·d⁻¹. After three (dill), four (sage), or five (parsley) weeks after sowing, data was collected.

Increasing indoor light intensity from 100 to 600 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ had different effects depending on the genera and CO₂ concentration. The fresh mass of parsley seedlings was 12% greater when grown under 100 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ compared to 600 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ (Fig. 2). The opposite trend occurred for sage seedlings where those grown under 400 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, had 17% greater fresh mass than those grown under 100 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ (Fig. 3). The influence of light intensity on dill fresh mass depended upon the CO₂ concentration provided (Fig. 4). When CO₂ concentration was elevated to 1200 ppm, plants grown under 600 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ had the greatest fresh mass. When CO₂ concentration was not elevated above ambient levels (400 ppm), plants grown under 400 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ had the greatest mass.

Besides fresh mass, another important factor to consider is seedling compactness. Seedlings grown under 100 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ tended to be floppy, elongated, and tangle together. Increasing light intensity resulted in more compact and sturdy seedlings that would potentially utilize less labor or be easier to automate transplanting.

Crops responded differently to elevated CO₂ as well. Increasing CO₂ concentrations did not influence the fresh mass of sage, but did increase the fresh mass of parsley. The greater CO₂ input increased fresh mass of dill only when the light intensity was high (600 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$).

Finished production

You may be thinking: Great, you have increased fresh mass at transplant, but that is not the product I am selling! That was our thought as well, so we trans-

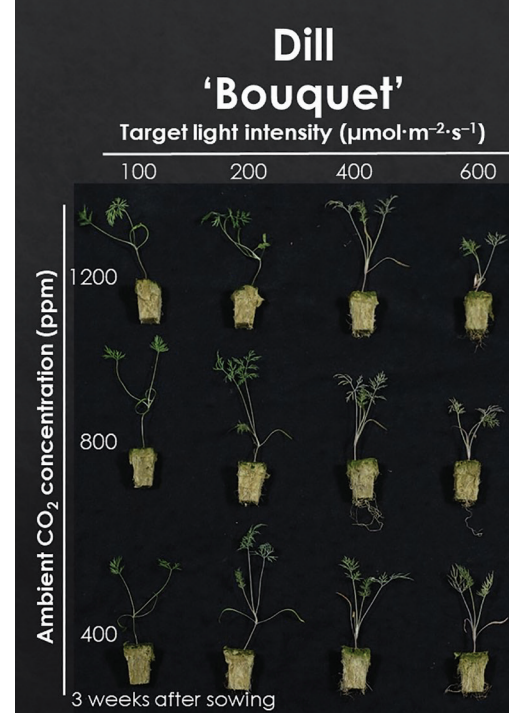


Figure 4. Dill seedlings grown under light intensities of 100, 200, 400, and 600 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ and CO₂ concentrations of 400, 800, and 1200 ppm. Picture was taken three weeks after sowing.

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Dill 'Bouquet'

Target light intensity ($\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$)

100 200 400 600

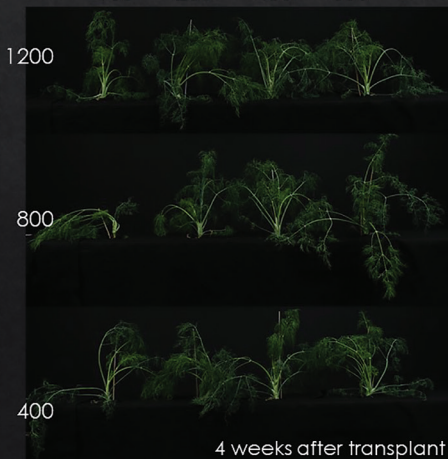


Figure 5. Dill plants grown in a common greenhouse environment (deep-water culture), four weeks after transplant. Seedlings were grown under light intensities of 100, 200, 400, and 600 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ and CO_2 concentrations of 400, 800, and 1200 ppm.

planted these seedlings into deep flow raft hydroponic systems and grew the plants in a common greenhouse environment with an average daily temperature of 73 °F and DLI of 14 $\text{mol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$ for four (dill and sage) or five (parsley) weeks.

We found that elevating the CO_2 concentration during the seedling stage did not influence any of the crops at harvest. However, increasing light intensity from 100 to 400 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ increased dill and sage yield by 47% and 69%, respectively (**Fig. 5**). Additionally, when dill seedlings were grown under higher light intensities, the stems were thicker and plants were less floppy at harvest (**Fig. 6**).

Efficiency implications

By sowing seeds in a 200-cell tray (200 in^2 per flat, 1 in^2 per cell), the planting density is 144 plants per ft^2 . Seedlings were transplanted 8-in apart with a planting density of 2.25 plants per ft^2 . Therefore, the planting density was 64 times greater during seedling production than finished (harvest) production. Additionally, in this study, the duration of dill seedling production was 3/4 that of finishing (three weeks compared to four weeks). Taking both the increased planting density and shorter production duration into account, the increase in

PRODUCTION

sole-source lighting cost per plant could be discounted by 64 (sage) to 85 (dill) times during seedling versus finished production.

Therefore, in this case, the cost per plant of increasing the light intensity

from 100 to 400 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ during propagation was ~4 to 5% that of the cost during finished production. Since the increase in yield at the finishing stage was 47% (dill) and 69% (sage) greater when seedlings were grown under

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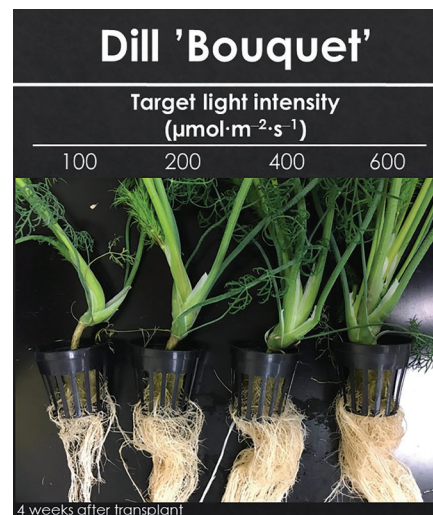


Figure 6. Dill plants grown in a common greenhouse environment (deep-water culture), four weeks after transplant. Seedlings were grown under light intensities of 100, 200, 400, and 600 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$.

400 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ compared to 100 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ (24 compared 6 $\text{mol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$), increasing light intensity during seedling production increases subsequent yield while reducing input costs.

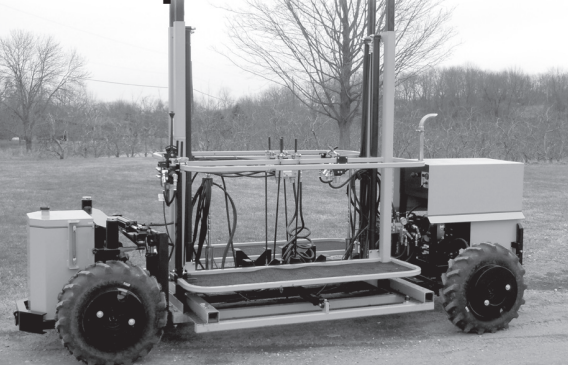
The bottom line

Elevating CO_2 concentration during young plant production did not have a long-term effect on plant growth or harvestable yield of the culinary herbs we have investigated. However, increasing light intensity during dill and sage seedling production, but not parsley, is a more effective strategy to increase subsequent yield.

Kellie Walters was a Ph.D. student at Michigan State University (MSU) and is now an Assistant Professor of Controlled Environment Plant Physiology in the Department of Plant Sciences at the University of Tennessee and Roberto Lopez is an Associate Professor and Controlled Environment/Floriculture Extension Specialist in the Department of Horticulture at MSU. The authors gratefully acknowledge Sean Tarr and Nate DuRussel for assistance, Fluence Bioengineering for LEDs, JR Peters for fertilizer, Grodan for substrate, Hydrofarm for hydroponic production systems, and MSU AgBioResearch Project GREEN, MSU Graduate School, and the USDA-NIFA for funding.

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