Extended Photoperiod During Lettuce Propagation

Trial

Protocol: 18-LUM-EW

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## Trial Summary

In both the greenhouse environment and growth chambers, LumiGrow researchers found that extending the photoperiod—while maintaining a constant daily light integral (DLI) between treatments—will promote the growth of lettuce (*Lactuca sativa* ‘Red Sails’ and *L. sativa* ‘Skyphos’; [growth chamber results](https://lumigrow.sharepoint.com/:p:/r/sites/researchteam/_layouts/15/doc.aspx?sourcedoc=%7B5c83b7ee-5f86-4ea0-8cff-a84fc6866e49%7D&action=edit&uid=%7B5C83B7EE-5F86-4EA0-8CFF-A84FC6866E49%7D&ListItemId=27201&ListId=%7BA4D8966B-33D0-4268-A094-7AD995B57A6A%7D&odsp=1&env=prod); [greenhouse results](https://lumigrow.sharepoint.com/:w:/r/sites/researchteam/_layouts/15/Doc.aspx?sourcedoc=%7B3F3BA73F-DD79-4C5D-858C-0B57833739E6%7D&file=GreenhouseLettuceSummaryv2.docx&action=default&mobileredirect=true)). This confirms past research by Koontz and Prince (1986) revealing that lengthening the photoperiod from 16 to 24 hours while maintaining constant radiation, increased the fresh weight of several *L. sativa* varieties by 48 to 135%.

This lengthened photoperiod, termed the “high-yield photoperiod”, could benefit growers by shortening production cycles, increasing yields per unit of energy consumed (g/Watt), and raising net profits. Lengthening the time in which supplemental fixtures radiate light—without increasing the overall DLI—may prove especially valuable to growers during winter months when there is minimal solar radiation.

Despite a replicable positive correlation between longer photoperiods and increased lettuce growth, the effect is not universal. When extending the photoperiod from 16- to 24-hours in summer greenhouse conditions (DLI: 19 mols\*m-2\*d-1), Dr. Ricardo Hernandez saw an increase in fresh weight and dry weight of *Lactuca sativa* ‘Skyphos’ and ‘Red Sails’ at transplant stage (14 days). Yet, he did not see this increase when harvesting at marketable weight (after 36 days).

Recently, LumiGrow found that *L. sativa* ‘Skyphos’ fresh and dry weights increased when extending the photoperiod in the greenhouse under excessive radiation (solar + supplemental DLI: >20 mols\*m-2\*d-1). Under the same conditions, *L. sativa* ‘Rex’ growth metrics did not increase in the extended photoperiod treatment. After repeating this experiment with lower light levels (solar + supplemental DLI ≈ 10 mols\*m-2\*d-1), LumiGrow research did not see an increase in the fresh weight, dry weight, or volume of ‘Rex’ or ‘Skyphos’.

In grow tents, LumiGrow research also found that three lettuce varieties (‘Bergam’s Green’, ‘Coastal Star’, and ‘Dragoon’) increased in fresh weight, dry weight, and volume as the photoperiod lengthened from 15 to 24 hours. This effect was most prominent after removing the variety effect from the analysis. However, after repeating this experiment by radiating ‘Bergam’s Green’ with either a 20- or 24-hour photoperiod, LumiGrow did not see a significant increase in lettuce fresh weight or volume.

Factors influencing whether a study finds photoperiod extension to increase lettuce growth include: the lettuce variety, the difference in the photoperiod length between treatments, if the lighting is sole source or supplemental, whether the experiment occurs during winter or summer months, the daily light integral, and the method of propagation (including time-to-transplant, photoperiod length, and light intensity). In the experiments above, we suspect that differences in propagation influenced whether extending the photoperiod increased growth.

Lighting during propagation greatly affects subsequent plant growth. The petunia variety, ‘Tiny Tunia Violet Ice’ flowered 21 days earlier when the 16-day propagation phase DLI increased from 1.4 to 10.7 mols\*m-2\*d-1. The propagation DLI promoted early flowering, and this flowering did not depend on the DLI during the production phase (Lopez and Runkle, 2008). Johkan et al. (2010) found that at harvest the quality of light during 17-days of propagation modified *L. sativa* ‘Banchu Red Fire’ growth parameters, carotenoid, and chlorophyll content. We hypothesize that the propagation photoperiod substantially influences future plant growth and may be a critical component of the high-yield photoperiod effect. We predict that as the propagation photoperiod increases from 15 to 21 hours, time-to-harvestable lettuce size (150-200 grams) will decrease, even when lettuce plants experience the same DLI and photoperiod during the production phase.

## Objective List

1. To determine if extending the propagation photoperiod will enhance *Lactuca sativa* ‘Cherokee’ growth at the transplant stage
2. To determine if the high-yield photoperiod occurs when lettuces remain below their respective sole-source lighting treatments for 21-days after propagation
3. To determine if after transplanting ‘Cherokee’ lettuces from grow tents into a hoophouse, the propagation photoperiod will affect marketable weight even when the photoperiod during the production phase (within the hoophouse) remains the same

## Treatments

Fifteen-hour, 18-hour, and 21-hour photoperiod treatments (3 replicate tents), with a DLI of 17 mol\*m-2\*d-1. We will sow 9 plug trays (105 plugs each, total seeds sowed: 945) and place each tray in a grow tent. After 12-days of propagation, we will transplant 18 plants into 4-inch pots, which will remain in the tent in which they germinated. We will transplant the remaining plants into NFT channels (closed-system) in a hoophouse. Twenty-one-days after transplant, we will harvest grow-tent plants (18 per tent). We will harvest hoophouse plants weekly (20 per treatment, starting 14-days after transplant) until they reach a marketable weight (150-200 grams).

**Table.** Experimental treatments and number of replicates per treatment.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **15-hour Photoperiod** | **18-hour Photoperiod** | **21-hour Photoperiod** |
| **Grow Tent Propagation Harvest** | 3  (20 plants) | 3  (20 plants) | 3  (20 plants) |
| **Grow Tent Final Harvest**  **(harvest at 21-days)** | 3  (54 plants) | 3  (54 plants) | 3  (54 plants) |
| **Hoophouse Harvest**  **(harvest a 9-, 26-, and 33-days after transplant)** | 18 plants | 18 plants | 18 plants |

## Expected Outcome

We predict that the response variables (dry weight (g), wet weight (g), and volume (cm3)) for *L. sativa* ‘Cherokee’ will be greatest in the 21-hour photoperiod treatment.

# Trial Details

## Plant Information

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Species | Varieties | Number | Container | Grow Space | Media | Spacing / Density | Starting Materials and Conditions |
| *Lactuca sativa* | ‘Cherokee’ | 180 | 7 x 15 plug tray | 3’ x 3’ x 6.5’  Grow Tent | Elle Plug | 105/Tray | Coated Seed |
| *Lactuca sativa* | ‘Cherokee’ | 162 | 3” x 3” x 2.33”  Square | 3’ x 3’ x 6.5’  Grow Tent | Elle Plug in Sunshine Grow Mix | 18/Chamber | Coated Seed |
| *Lactuca sativa* | ‘Cherokee’ | ≈500 | Plug | Hoophouse (NFT Channels) | Elle Plug | 1/Channel Hole (approx. 6 inch spacing) | Coated Seed |

\*We will sow 945 seeds total on day 1. We will harvest 180 seedlings on day 12. We will transplant 162 seedlings (18 per tent) to four-inch pots on day 12. We will transplant approximately 500 seedlings to NFT channels in the hoophouse on day 12.

## Lighting Conditions (Main Lab)

Photoperiod (hours); PPFD/Intensity (µmol·m-2·s-1); DLI (mol·m-2·d-1)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Lighting Conditions | Lighting Sources | Quality | Lighting Time Segment | PPFD | DLI | Photoperiod |
| Supplemental/Sole Source | Two Pro 325s, or one Pro 650 | 75R:5W:20B | 16:00 to 07:00 | 315 | 17.01 | 15 |
| Supplemental/Sole Source | Two Pro 325s, or one Pro 650 | 75R:5W:20B | 16:00 to 10:00 | 262 | 16.98 | 18 |
| Supplemental/Sole Source | Two Pro 325s, or one Pro 650 | 75R:5W:20B | 16:00 to 13:00 | 225 | 17.01 | 21 |

\*Lights and fans will remain off every day from 13:00 to 16:00 to reduce noise levels during lab sections at Cabrillo College.

## Lighting Conditions (Hoophouse)

Photoperiod (hours); I=Intensity (µmol·m-2·s-1); DLI (mol·m-2·d-1)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Lighting Conditions | Lighting Sources | Quality | Lighting Time Segment | DLI | Photo-period |
| Supplemental/Sole Source | Pro 325 | 75R:5W:20B | 06:00 to 04:00 | 17 | 22 |

\*Note that we will run the DLI control algorithm for this trial with a photoperiod of 22 hours, min PPFD of

50 µmol·m-2·s-1, max PPFD of 400 µmol·m-2·s-1, and a DLI target of 17 mol·m-2·d-1

## Lighting Plan (Main Lab)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Fixture Type | Hang Height | Fixture Density | Lighting Footprint | Color Ratio | Total Grow Area | Total Fixture Count |
| Pro 325 or Pro 650 | 5.5’ | 1 (650) or 2 (325s)/Chamber | N/A | 75R:5W:20B | 2’ x 2.5’ | 15 |

## Lighting Plan (Hoophouse, double-polyvinyl)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Fixture Type | Hang Height | Fixture Density | Lighting Footprint | Color Ratio | Total Grow Area | Total Fixture Count |
| Pro 325 | 4’ | 1/meter (?) | N/A | 75R:5W:20B | 819 ft2 | 18 |

## Measurements, Measurement Tools, and Measurement Protocol

**Harvest Data**

|  |  |  |  |
| --- | --- | --- | --- |
| Measurement | Unit | Tools Needed | Procedure |
| Fresh Weight | g | Balance | Saturate media 3 hours before harvest. Cut stem of plant at soil line and place on scale. |
| Dry Weight | g | Balance | Place in paper bag and dry for 4 days at 70°C. Remove from bag and weigh. |
| Volume | cm3 | Ruler and/or measuring tape | Measure plant height (bench top to highest leaf) and two widths (greatest width, and the width that is 90 degrees from the greatest width). Calculate the volume of the cylindrical plant (cylinder volume = height \* πr2, r = (width1 + width2) ÷ 4). |
| Photographs | .jpeg | Camera | Set up photo station using black velvet cloth. Set up tripod and photograph several plants per treatment. Also photograph a selection of one individual plant from each treatment in the same photograph. |

**Environmental Data**

|  |  |  |  |
| --- | --- | --- | --- |
| Measurement | Unit | Equipment Needed | Procedure |
| Fertigation Solution | EC / pH | EC / pH probe | Record EC and pH when mixing fertigation |
| Irrigation | # / time | Count | Water from below by pumping water from reservoir to tents |
| Temperature | Celsius | Elitech Data Logger | Assure temperatures are roughly equivalent (+ or – 0.5 degrees Celsius on average) between tents. Upload data and average. |
| Humidity | % | Elitech Data Logger | Assure humidities are roughly equivalent (+ or – 2%) between tents. Upload data and average. |

## Analysis and Statistical Tests

A one-way ANOVA (explanatory variable: propagation photoperiod) and Tukey HSD will separate means at the α = .05 level. We will analyze the sole-source lighting results by considering the experimental unit to be the grow tent (n = 3 for each treatment, there will be 18 pseudoreplicate lettuces within each replicate tent). In the hoophouse, the individual lettuce will serve as a replicate and we will harvest 3 lettuces from each channel at every harvest date (27 lettuces per east and west block, 54 total).

## Conclusions and Final Report

LumiGrow will produce a final report within 30 days of this trial’s end.

## Timeline

|  |  |  |  |
| --- | --- | --- | --- |
| Activity | Date | Time (hours) | Procedure |
| Growth Chamber Preparation | 09/27 and 09/28 | 14 | Create grow tent treatment labels (Template), assure lights are functioning, test irrigation, equilibrate temperature/humidity between tents, sterilize grow tent floors ([Link to Procedure](https://lumigrow.sharepoint.com/:w:/s/researchteam/EUTzI8PNAUdHhWshYxAeJBUBIw5DVmcYynKyPnaBnwCSSg?e=g2IJ2S)) |
| Sow Lettuce | 10/05 | 3 | Sow *L*. *sativa* seed ([Link to Procedure](https://lumigrow.sharepoint.com/:w:/s/researchteam/EWShDKx2p-5CrfXtLu7dxnsBbxaLIIOOP6m_-0BL_agePA?e=uqpg7D)) |
| Transplant Lettuce | 10/17 | 2 | With Hort 1A class, at day 14, transplant 18 lettuces from plug trays to 3” x 3” x 2.33” square pots (for grow tents, [Link to Procedure](https://lumigrow.sharepoint.com/:w:/s/researchteam/EXLUQ6NUJCZDrGVhoxHZjYwBoONCFtKzr0_uk-5maoY3MQ?e=A2Qwpi)), and also transplant approximately 500 plants (10 NFT channels worth per treatment) to NFT channels in hoophouse. We will block by west and east side of the hoophouse with 15 channels across tables 1 and 2 (west side), and 15 channels across tables 4 and 5 (east side). We will randomize the order of the treatments within these blocks. |
| Harvest Lettuce Seedlings from Grow Tents | 10/17 | 4 | Obtain fresh weight of 12-day old seedlings (transplant stage), 20 per tent. |
| Harvest Hoophouse Lettuces | 10/26 | 6 | Obtain fresh weight and volume of lettuces 9-days after transplant into hoophouse #4, 18 per treatment |
| Harvest Hoophouse Lettuces | 11/12 | 6 | Obtain fresh weight and volume of lettuces 26-days after transplant into hoophouse #4, 18 per treatment |
| Harvest Grow Tent Lettuces | 11/07 | 8 | Fully saturate pots by filling trays with fertigation below pots, 3 hours prior to obtaining fresh weight. Take height and width measurements. ([Link to Procedure](https://lumigrow.sharepoint.com/:w:/s/researchteam/ETz8pYZapqxPvn9KDN5P6YEBoN0XXAU0cCz6C0fnzRGyxg?e=xEa6j7)) |
| Harvest Hoophouse Lettuces | 11/14 | 6 | Obtain fresh weight and volume of lettuces 28-days after transplant in hoophouse #4, 18 per treatment (students data collection) |
| Harvest Hoophouse Lettuces | 11/19 | 6 | Obtain fresh weight and volume of lettuces 33-days after transplant in hoophouse #4, 18 per treatment. |
| Data Analysis and Final Report | 11/22 | 8 | Report Results at Thursday’s Research Meeting |

\*Immediately after each harvest, we will dry lettuces at 70°C and weigh them after 96 hours of drying

## References (in order of appearance)

Koontz, H.V. and R.P. Prince. 1986. Effect of 16 and 24 Hours Daily Radiation (Light) on Lettuce Growth. HortScience 2(1):123.124.

Lopez, R. and E.S. Runkle. 2008. Photosynthetic Daily Light Integral during Propagation Influences Rooting and Growth of Cuttings and Subsequent Development of New Guinea Impatiens and Petunia. HortScience 43(7):2052-2059.

Johkan, M., K. Shoji, F. Goto, S.N. Hashida, and T. Yoshihara. 2010. Blue light-emitting diode light irradiation of seedlings improves seedling quality and growth after transplanting in red leaf lettuce. HortScience 45(12): 1809-1814.