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Does Light Quality Influence Arabidopsis thaliana Growth in Controlled-Environments?

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Introduction:

Arabidopsis thaliana (thale cress) is a model crop used globally in plant science research programs. Although *A. thaliana* (At) tends to be produced successfully with minimal input, many accessions tend to be photoperiod sensitive. Photoperiod sensitivity can add another layer of difficulty when attempting to produce a plant to physiological maturity in controlled environments. The At accession used in this study, however, tends to flower when days are long and nights are short – which is simply called a long day plant.

Common strategies used to successfully produce long day At accessions are (1) starting seedlings under short days to promote robust vegetative growth before lengthening the photoperiod to induce flowering or (2) simply growing entirely under long days.

Although photoperiod sensitivity is very important when considering the best lighting solution to optimize At, it is equally important to consider sufficient light intensity. Light intensity generally refers to the number of photons (within the photosynthetically active radiation range of the visible light spectrum) that is intercepted over a given area per measured time.

The required photoperiod and light intensity are both important factors when selecting the proper environment for At production, but is light quality also influential?

This study examines the use of diverse lamp types, with inherently different spectral attributes, to determine light quality influence on At growth in controlled environments.

Materials and Methods:

Equipment - Growth Chamber

Two identical growth chambers (Percival Scientific, Model AR75L3) were selected for this study at the HLA Plant Growth Facility. Each chamber was fitted with two equally sized platforms (approximately 2.5’ x 5’) with their own light canopies overhead. Light canopies accommodated both fluorescent and pendant lights (E26 Base). New fluorescent bulbs (Philips, Model F32T8/TL941) were added to ensure uniform performance and distribution across all chamber platforms for this study. The pendant sockets, however, were fitted with diverse lamps designed to be this study’s experimental treatment groups. (1) The first platform received no pendant lights (controlled experiment), (2) the second platform received 730 nm LEDs (Percival Scientific, Model Far Red ELD-038), (3) the third platform received tungsten incandescent lamps (Bulbrite,

25 w, 2700 k, 130 v), and (4) the fourth platform received incandescent style LED lamps (RAB, Model 10w, A19, 2700 k, 120 v).

Environment – Growth Chamber:

A quantum light sensor (Li-Cor, Model LI-250 datalogger with Model QUANTUM sensor) was used to help normalize light intensity across all treatments. Platform to light canopy distances were adjusted to provide 150 µmol/m^2/sec (+- 10%) PPFD.

A 16-hour photoperiod was implemented concurrent with 22 C day/night and 60% RH across all treatments.

Recommendations for the aforementioned environmental conditions in this study were based on guidelines provided within the NCERA-101 "Plant Growth Chamber Handbook."

Materials and Methods

The controlled experiment and treatments groups each received four horticultural trays (HC Companies, 1020 Standard Full Depth Vacuum Flat, SKU TVA111210) containing eighteen individual cells (HC Companies, 1801 Deep Insert, SKU IJT18010). Trays had perforated bottoms which allowed for sub-irrigation after being placed in solid bottom shallow depth trays (T.O. Plastics, White Display Flat, Product Code 760247C).

Cell packs were filled with soilless media composed of 50/50 (v/v) superior germination mix (Berger BM2) and calcined clay (Turface Athletics, MVP) before being sown with *Arabidopsis thaliana* 'Col-0 WT' seed on surface. A fine dusting of Berger was used to cover seeds from light.

Each tray was covered with a standard propagation dome (T.O. Plastics, Product Code 760549C) to ensure media remained moist and seeds did not desiccate. Once plants germinated and emerged from media surface, domes were removed for the remainder of the study. All cells were thinned to one plant.

Flats were sub-irrigated exclusively and received 150 ppm N (ICL Specialty Fertilizers, Peters Professional 20-3-19 Petunia Special with Black Iron) fertilizer treatments on alternate watering cycles. No pesticides were required.

Flowering dates were recorded per treatment once 50% of samples were in anthesis. Also, basal rosette diameter measurements were recorded at the same time point or soon thereafter.

Treatments received no additional water once 50% of the samples had ceased flowering and were senescing. Samples were allowed to dry in situ prior to harvest. At harvest, the number of distinct inflorescence stems were recorded before all above ground biomass was removed and placed in a 65 C drying oven for 48 hours. Oven-dry weights were recorded once removed from the oven.

Results:

As noted in Figure #1, there are a variety of flowering dates based on treatment. The controlled experiment plants flowered at 31 days after planting (DAP) as did plants within the incandescent style LED treatment (Image #3). Since this data was collected through observation, it is difficult to discern if there is a significant difference in flowering dates between the control and tungsten incandescence (27 DAP) treatment (Image #2). However, there is a notable difference between the flowering dates in the controlled group as compared to the 730 nm LED (20 DAP) treatment (Image #1). This study showed that the 730 nm LED treatment flowered 35% earlier than the controlled experiment.

Figure #1 - Observation of Flowering Times

Groups	*Days to Flower **
CONTROL	31
730 LED	20
W INC	27
LED INC	31

*Observations Only

Image #1 – 730 nm LED plants flowering 21 DAP vs. controlled experiment

Image #2 – Tungsten incandescent plants flowering at 27 DAP vs. controlled experiment.

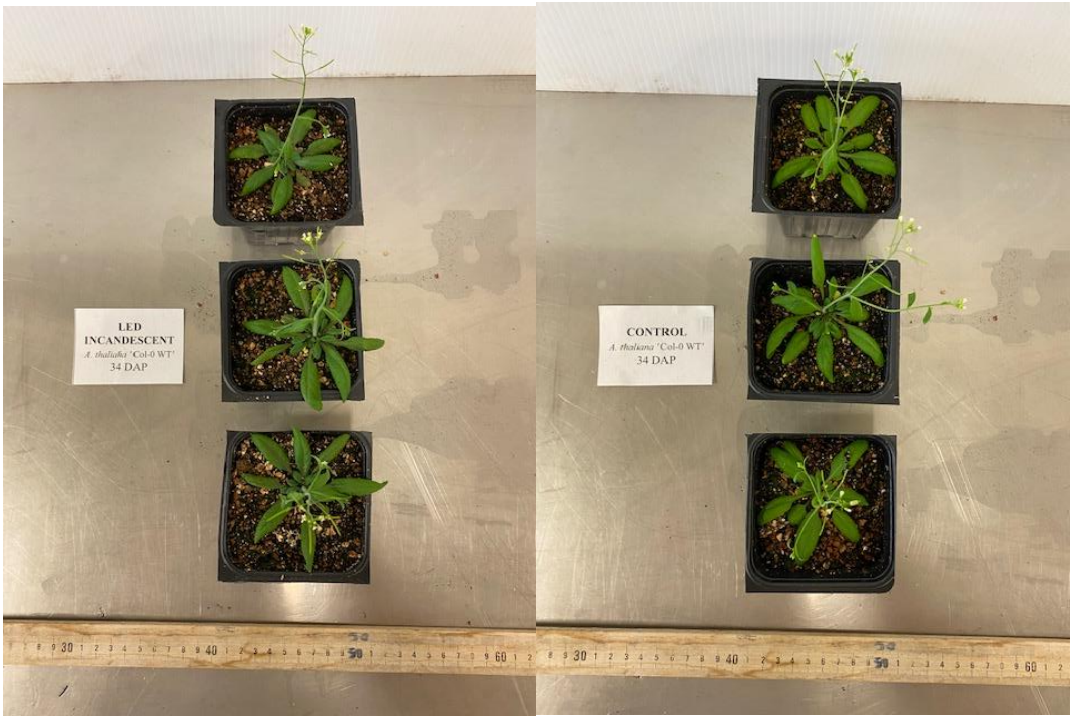

Image #3 – Incandescent style LED plants flowering at 31 DAP vs. controlled experiment.

On or within two days of recorded flowering dates, basal rosette diameter was measured and recorded for all plants across all treatments. Figure #2 shows the sample size (n), mean rosette diameter at initial flowering (mm), and p-value. The incandescent LED is shown to have the largest mean rosette diameter, while the 730 nm LED has the smallest diameter. Using a statistical t-test for means, where variance was assumed to be equal, all treatments had a p-value < 0.05. The null hypothesis (treatment and control means are similar) must be rejected. All treatments in this experiment had a significant difference in mean rosette diameter compared to the controlled experiment.

Figure #2 - Comparing Mean Rosette Diameter at Early Flowering (Using T-Test Assuming Equal Variances)

Groups	*N*	*Mean Rosette Diameter at Early Flowering (mm)*	*P-Value*
CONTROL	72	77.98	
730 LED	72	34.32	1.613E-73
W INC	72	70.71	1.304E-05
LED INC	72	84.67	4.198E-06

Sig p=0.05

Plants were harvested at two time points. The tungsten incandescent treatment was harvested 63 DAP and the other two treatments and the controlled experiment were harvested at 71 DAP. Pronounced inflorescence stems were counted and recorded, and their means are shown in Figure #3. A similar statistical tool was used to compare mean inflorescence count between the experimental control and treatment groups. The mean inflorescence stem count was greatest in both the incandescent LED and tungsten LED treatments (no statistical analysis was used to examine mean differences between these two treatments) and least in the 730 nm LED treatment. All treatments in this experiment had a significant difference in mean inflorescence stem count at maturity as compared to the controlled experiment.

Figure #3 - Comparing Mean Inflorescence Stem Count at Maturity (Using T-Test Assuming Equal Variances)

Groups	*N*	*Mean Inflorescence Stem Count at Maturity*	*P-Value*
CONTROL	54	4.315	
730 LED	54	3.547	3.61E-08
W INC	54	4.574	0.04524441
LED INC	54	4.630	0.02947977

Sig p=0.05

The mean oven-dry weights for all plants within this study are shown by experimental unit in Figure #4. Using a similar statistical tool as before, the mean oven-dry weights for plants in under incandescent LEDs is not significantly different than the controlled experimental mean

weights (95% CI). The 730 nm LED treatment appeared to have the lowest mean oven-dry weights in this study. As before, no statistical model was employed to compare means between treatments.

Figure #4 – Comparing Mean Oven-Dry Weights at Maturity (Using T-Test Assuming Equal Variances)

Groups	*N*	*Mean Oven-Dry Weight at Maturity (g)*	*P-Value*
CONTROL	54	1.043	
730 LED	54	0.504	4.007E-17
W INC	54	0.660	8.508E-11
LED INC	54	0.974	0.232

Sig p=0.05

Conclusion:

When comparing mean rosette diameter, inflorescence stem count, and oven-dry weights between the controlled experiment and treatment groups, there appears to be widespread significant differences in vegetative and flowering attributes.

The controlled experiment and incandescent LED treatment appear to be synchronous in terms of days to flowering and oven-dry biomass weights. Although the mean rosette diameter and inflorescent count are significantly different in this study, further experimental replications could veritably show these values being similar. Analyzing light quality under the incandescent LED treatment and comparing to the control (no pendant lights) might reveal the overall spectral distribution to be very similar. This would help resolve similarities in these measurements.

The tungsten incandescent treatment is the least mentioned in this study. These lamps are much more difficult to procure due to their inefficiency and planned obsolescence from the marketplace. Historically, these bulbs were employed in horticultural production to help extend the daylength. Daylength extension could be employed at the beginning or end of day or provided as a night interruption tool. Tungsten incandescent bulbs provide a rich far-red spectrum that helps govern certain responses in plants. It is entirely possible the tungsten lamp light quality blending with the background light produced by fluorescent bulbs could be the reason for earlier flowering and smaller rosettes. According to Runkle, “some LDP (sic long day plants) flower most rapidly when the long-day lighting includes both red and far-red light.” Another important note is the Kelvin rating of 2700 k between both tungsten and incandescent LEDs. The light appearance of both treatments is considered warm white by Westinghouse (www.westinghouselighting.com/color-temperature.aspx), but results appeared to be less synchronous than between the controlled group and incandescent LEDs. This might suggest that the spectrum produced between the tungsten incandescent and incandescent LEDs appear the same, but in fact are different in quality.

The treatment with the most pronounced differences in days to flowering, rosette diameter, inflorescent count, and oven-dry biomass weights as compared to the control is the 730 nm LED. Plants produced under this far-red light resulted in rapid flowering and the smallest basal rosettes. Although these plants flowered rapidly, there is no inference being made as to the difference in seed yield between this treatment and the controlled experiment. Comparing the spectral distribution of light between the controlled experiment and this treatment might help solve their dissimilarities of vegetative and flowering attributes. We plan to address this question in a subsequent study.

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