# LED's: New Lighting Alternative for Greenhouses

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In the far north of Minnesota (>40N° lat.), commercial production of high quality, high light-requiring greenhouse crops typically necessitates the addition of supplemental lighting during the period of October – March (Nelson, 2003). The visible spectrum of light (400 – 700 nm) includes the rainbow of colors we often see refracted, but the most important regions for plant photosynthesis are the red and blue bands. Blue light by itself produces shorter plants (reduced internode lengths) which are dark in color. In contrast, red light produces plants with long internodes with softer growth (Nelson, 2003). Typically, when light intensity is suboptimal during the winter months greenhouse growers will use supplemental lighting to maximize crop growth by increasing the rate of photosynthesis.

Our traditional use of supplemental lighting commenced with the use of incandescent lamps, followed by fluorescent tubes, and then high intensity discharge (HID) lamps. Each category of lights has various attributes that make them useful for similar or different phases of crop growth. For instance, for photoperiod control, incandescent lamps are frequently used to supply low levels of light (5-10 foot-candles) during the dark period to institute a long day effect. Incandescent lamps (tungsten filaments) are high in far-red light, which would cause crops to stretch (longer internodes) if they were used as the sole light source for photosynthesis. In addition, incandescent lamps also generate heat and have low efficiency (only converting 7% of the electricity into light energy). Fluorescent lamps are the most commonly used lights for germination chambers and small growing rooms; they rarely are used for finishing crops in the greenhouse. Fluorescent lights have low wattage which increases the number of lamps required thereby increasing shadows over crops (Mastalerz, 1969). The most efficient fluorescent lights are the cool white and warm white tubes (primarily light emission in the blue region), which have an efficiency of 20% (Nelson, 2003). The preferred type of supplemental lighting to date has been HID lamps, which come in a variety of forms: metal halide, high-pressure mercury, and high-pressure sodium. Most commonly, greenhouse growers use high-pressure sodium (HPS) lamps as they are less expensive to operate or purchase when compared with other types of HID lamps (Nelson, 2003). HPS lamps (400 – 1,000 watts) emit light in the visible (400-700nm) and invisible (700-850 nm) ranges, but peak emission is in the yellow light (~589 nm) region. HPS lamps convert 25% of the electricity into light energy but generate heat and noise, as well as having short-lived bulbs. Greenhouse growers typically manage to overcome the costly electrical use of HPS HID lamps by instituting cyclic lighting or lighting during off-peak hours of demand.

During spring semester, 2005, greenhouse management class (Hort 3002W) at the University of Minnesota had the opportunity to conduct research on a new alternative to HID lamps. One experimental group in class studied an alternative lighting source: light-emitting diodes (LEDs). You are probably already familiar with LED lights which are used as low electricity lights on household or industrial appliances, cell phones, etc. Typically these LED lights are red in color. LEDs have a variety of benefits (Table 1) which could make them readily adaptable to commercial greenhouse production use, provided comparable plant growth and cost-savings are realized (http://www.growwithleds.com/). They are already being researched by NASA scientists for use in growing plants in space (http://www.space.com/businesstechnology/technology/light_farming_010926.html) and kits for homeowners on this planet are creating a growing interest in these lighting alternatives. Several space shuttle missions have already used the Astroculture™ Plant Growth Chambers to grow lettuce, soybeans, and other crops in space (http://wcsar.engr.wisc.edu/asc-gc.html). LED lights would have the potential to greatly increase energy use efficiency of commercial greenhouse lighting, thereby passing on significant savings to growers and consumers. While the initial investment in LED lighting is higher ($1,760) than HPS HID lamps ($400), the cost-savings over a 7-year period are $2,291 due to their lower energy use and bulb longevity (http://www.growwithleds.com/breakevenchart.htm).

We were delighted to have the opportunity of experimenting with these LED lights to compare plant growth with HPS HID lighting. The objective of our first experiment was to test blue/red LED lights with HPS HID lamps (control) along with natural sunlight and measure plant growth differences.

**Materials & Methods.**

*Growing Environment.* Three lighting treatments were used in this study: natural, LED, and HID. The natural light treatment consisted of placing the plants on the greenhouse bench at a height of 105 cm or 3'6" (House 415-B4, U of M greenhouses, St. Paul campus) with a day/night temperature of 22/20 °C. Plants in this treatment did not receive supplemental lighting of any kind and grew under the natural daylight conditions (Feb. – May, 2005). One HPS HID lamp (400 watts) was placed 180 cm above the bench height for supplemental lighting. Light measurements at plant height under the HPS HID light treatment were used as the basis for positioning the LED lights in the other chamber. One Model 480 LED kit (8 red LED bulbs, 4 blue 70 diode bulbs, 12 track light fixtures, 2 - 4' tracks, 2 cord sets) plus 40 diode blue bulbs were loaned for use in this experiment by Mark Fleck (Grow with LEDs, Lakeville, MN). The LED lights were installed at the same height as the HPS HID light. LED and HID lights were positioned to ensure that each treatment received an equal level of photosynthetically active radiation. Bench height in the LED treatment was modified to a position of ~90 cm below the LEDs.

Two chambers (240 cm length x 150 cm width x 210 cm height) were constructed on a greenhouse bench adjacent to the natural light treatment to accommodate the LED and HID light treatments. The bench height was the same as the natural light treatment. The chambers were surrounded by black plastic to prevent light contamination. Air vents and circulatory fans were added when the day/night temperature began increasing during the growing season as the experiment progressed.

*Plant Material.* The students chose two crops to grow in this experiment. Hungarian yellow wax peppers, *Capsicum annuum* 'Hungarian', were grown to demonstrate potential growth differences, branching habits, as well as flowering and fruiting potential. English daisies, *Bellis perennis* 'Monstrosa', were grown to demonstrate leaf unfolding rates, the impact of lighting on rosette growth habits, and flowering. Seeds from each crop were sown in early February, 2005, in 288 plug trays with germination mix, and grown under the lighting treatments. At the second true-leaf stage, plants were transplanted into 4" square pots and spaced appropriately in a randomized complete block design (with species as the blocks). There were n=15 replications (plants) in each lighting treatment. Plants were fertilized with a biweekly application of 200 ppm N using 20-10-20 soluble fertilizer. Standard pest and disease control measures were implemented for all treatments as necessary during the experiment.

Data was collected on plant height, measured weekly for seven weeks. Other traits such as flowering, fruiting, etc. were noted but are not reported herein. Quantitative data was analyzed using the Statistical Package for the Social Sciences (SPSS, 2001; Version 11.0) for analyses of variance and mean separations.

**Results and Discussion.**

Plant height varied significantly across weeks (F=12.98, $P \leq 0.001$), as would be expected for plant growth (Table 2). The pooled mean plant height for the natural light treatment was the highest (19.57 cm) and highly significantly different than the two lighting treatments (F=6.9, $P \leq 0.001$). The LED treatment had a pooled mean height of 15.24 cm and the HPS HID lights were 13.91 cm tall (Figure 1; Table 2). There was no statistically significant difference between the LED and HPS HID lights for plant height. Thus, LED lights appear comparable for plant growth in this experiment. There were no apparent differences in plant structure for the rosetted English daisies.

The reduced plant height with both supplemental lighting treatments compared with the natural light were most likely due to elevated temperatures which may have shut down photosynthesis. There was a slight delay in the installation of the ventilation system, which meant a reduction in plant growth during this time period.

Flowering and fruiting in the lighting treatments commenced ~2 weeks later than the natural light conditions, due to the warmer temperatures. Since the class semester ended before the plants had completed flowering and/or fruiting, additional measurements are being taken to measure differences. We plan on subsequent experimentation with the LED lights to answer further questions arising from this study. Nonetheless, it appears that LED lights may be an acceptable alternative to HPS HID lighting in greenhouses. If you're interested in learning more about LED lighting technology, visit the LED website: http://www.growwithleds.com/

**References.**

Nelson, P.V. 2003. Greenhouse operation & management. 6th Ed. Prentice Hall, Upper Saddle River, N.J.

SPSS. 2001. SPSS, Statistical package for the social sciences, for Windows. SPSS Inc., Chicago, IL.

Table 1. The many benefits of using LED lighting *in lieu* of high pressure sodium, high intensity discharge (HID) lamps for greenhouse growers (http://www.growwithleds.com/).

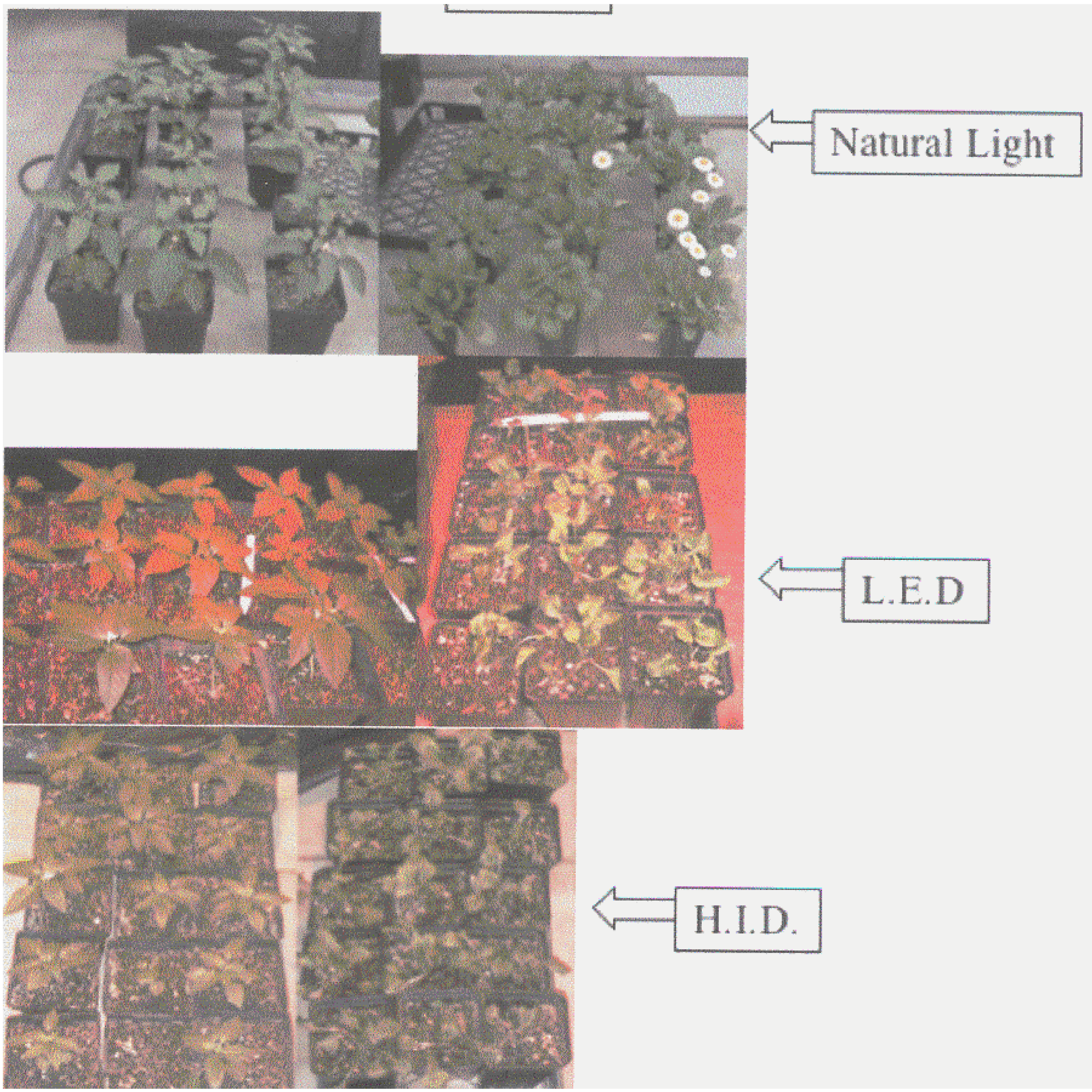
| | |
|---|---|
| **They're simple to use** | LED lights are installed into light bulb sockets. Virtually no reflectors, ballasts, or cooling fans are required. |
| **They have a long bulb life** | Average life of a LED bulb lasts 7-10 years. |
| **They're efficient** | LED lights produce light in the red and blue spectra which plants use for photosynthesis. |
| **They're cool** | While the lights are warm when touched, they're cool enough that you can grow a crop directly underneath them. In addition, LED's will not generate significant levels of heat, which will save in cooling costs. |
| **They're low cost** | LED lights use 20%-30% of the electricity consumption by HID lighting. They will pay for themselves very quickly. |
| **They have versatility** | If you want to enhance just vegetative growth, use only the blue LED lights. The red LEDs can be used to promote fruiting and flowering. Or, if you want both aspects of plant growth, use a red/blue LED combination. |
| **They're quiet** | LEDs do not have the hum or buzz typically associated with ballasts in fluorescent or HID lamps. They completely silent. |
| **They're colorful** | You'll have a different color spectrum in your greenhouses! The yellow lighting from high pressure sodium HID lamps will be replaced by blue and red colors. |

Table 2. Mean plant height (cm) measured over seven weeks of *Capsicum annuum* 'Hungarian' and *Bellis perennis* 'Monstrosa' grown under natural light, LED, and HPS HID lamps.

| **Week No.** | **Natural Light** | **LED** | **HPS HID** | **Pooled Height by week**[a] |
|---|---|---|---|---|
| 1 | 8.4 | 8.4 | 7.8 | **8.2 a** |
| 2 | 10.5 | 8.4 | 9.1 | **10.9 a** |
| 3 | 15.2 | 12.7 | 11.9 | **13.3 ab** |
| 4 | 19.9 | 13.9 | 13.4 | **15.3 ab** |
| 5 | 24.0 | 15.4 | 14.9 | **18.2 b** |
| 6 | 28.1 | 17.1 | 16.3 | **23.4 c** |
| 7 | 32.2 | 19.2 | 18.6 | **24.6 c** |
| **Pooled Mean**[b] | **19.6 b** | **15.2 a** | **13.9 a** | |

[a] Mean separations: Tukey's Honestly Significant Different (HSD) test at the 5% level (á=0.05). The mean square error (MSE) = 129.7. Means followed by different letters are significantly different.
[b] 5% HSD. MSE = 129.7

Figure 1. Comparative growth of peppers (left; *Capsicum annuum* ‘Hungarian’) and English daisies (right; *Bellis perennis* ‘Monstrosa’) on April 11, 2005, under natural light conditions (greenhouse conditions, no supplemental lighting), L.E.D. lights (note the red/blue coloration from the lights), and H.I.D. lights (note the typical yellow color from the tungsten lamps).


Natural Light
L.E.D
H.I.D.