Project Report

Chena Hot Springs Resort, home of the ChenaFresh controlled environment production greenhouse, fodder system and gardens is proud to report the involvement and developments of innovative new technologies for greenhouse crop production. With financial support from the State of Alaska Division of Agriculture, Alaska Agriculture Innovation Program we were able to conduct the project titled "Improved vegetable growth in greenhouses by using tuned LED lights to enhance photosynthesis"

The project entailed the evaluation of a variety of LED (light emitting diode) light arrays for the purpose of growing tomatoes, lettuce and other products.
The project focused on several attributes all relative to photosynthetic control of the crop.

1. Evaluated current crop yield and productivity at different times of the production cycle to establish baseline production criteria.
2. Evaluated the spectral output of a variety of light sources to be compared in the project.
3. Developed a light prescription to be used to build LED arrays for the project.
4. Identified a feasible spectral quality and output levels of the LED arrays for the project.
5. Developed and installed a large LED array utilizing the information gained to maximize crop production in a controlled environment.

The concept of this innovation is based in identifying and configuring several wavelengths emitted by the diodes in the LED lamp those in the absorption spectrum of the plants utilized by the photosynthetic process. When this match is identified we will have optimized the efficient use of the input energy to the plant and enabled it to be grown more efficiently.

The output spectrum of the LED lamp array depends upon which diodes of a particular output wavelength are selected and arranged. Although the spectral contribution of an individual diode represents only a single peak at a single color, the envelope from the sum of the output spectra of all of the diodes taken together from one lamp can be made to match the photosynthetic spectra of any plant. This means that far less energy is wasted in LED lamps for this illumination process than the use of standard incandescent or fluorescent lamps. Commercial, year-round growing operations, particularly in Alaska, could benefit from the energy savings that would result when using LED grow lights. The winter production period requires large amounts of heat and electrical energy, savings due to the use of tunable LED grow lights could make the difference between a loosing and income producing proposition.

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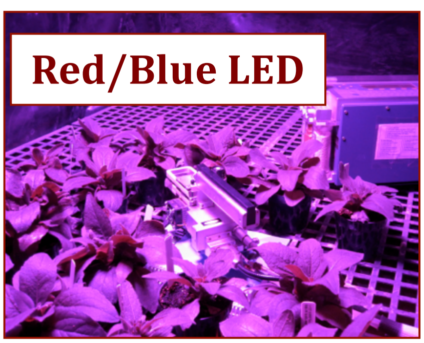
Corporate Office (907) 488-1505 Office Fax (907) 488-4058 Resort (907) 451-8104

The greenhouse at Chena Hot Springs is 6000 sqft, erected in 2006. The product from this greenhouse and daily feeds approximately 200 people per day who work at or visit Chena Hot Springs. It is powered by a geothermal reservoir producing vegetables for consumption every day. As a production greenhouse it serves as the "control" on this experiment against which we can measure the test results and success of efforts. The final outcome of this investigation will be to acquire the specific knowledge of the characteristics of specific grow light products and evaluate their success in producing cheaper and better produce.

Project implementation

The project was conducted at two different locations, Primarily Chena Hot Springs Resort – Chenafresh Greenhouse, and the University of Alaska Fairbanks Agricultural and Forestry Experiment Station, Controlled Environment Agriculture Laboratory in Fairbanks. The UAF location was used to conduct the analytical photosynthetic evaluation of the different lamp types being used. The UAF site was necessary in order to have access to the very delicate and expensive instrumentation.

At UAF several replications of lettuce and black-eye Susan was grown under different LED light scenarios to identify the optimum light spectra and light intensity necessary to activate and modulate photosynthesis. Black-eyed Susan is a test subject that is used for photomorphological research and very photo reactive. The following are photographs of this activity.



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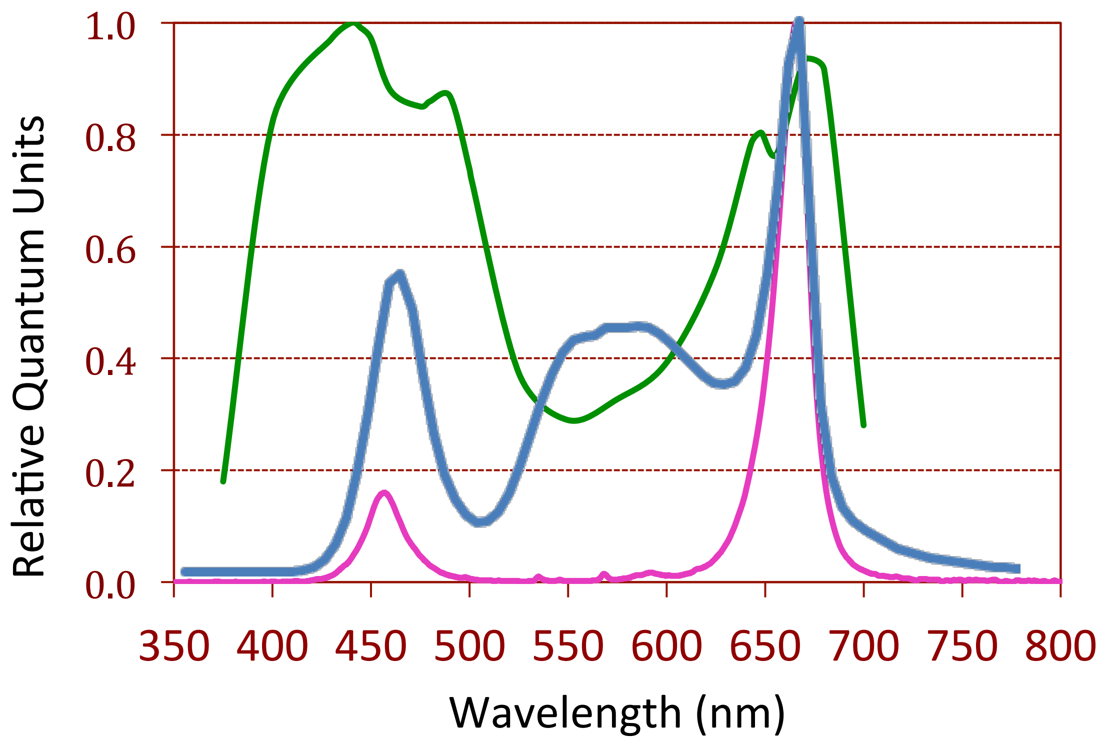
Photsynthetic Evaluation

The following chart represents the ideal spectrum for activating photosynthetic activity within the plant. The **GREEN** line is the spectral needs of the plant. The **RED** line represents the spectral output of the red and blue led. The **BLUE** line represents the spectra that was selected for the LED arrays that was purchased. This chart identifies the peak in the 460nm (blue) range and t he that we have identified as essential including:red 630nm, Far Red 660nm, Blue 460nm, Yellow 610nm, Orange 615nm.



Over the course of a year the production of lettuce and tomato crops at Chena Hot Springs were evaluated for production. It was possible to make an early determination for lettuce grown at the resort. However, the results need to be refined with further research to be considered conclusive. The project did provide preliminary information needed to develop a LED array for the lettuce production necessary for this activity.

The effects of the LED arrays were measured against the growth rate and size of the lettuce varieties in production. The lettuce plants were evaluated for leaf size, stem elongation, ability to bolt, and time to finish. The desirable lettuce plant was characterized as the plant that is grown under natural light for the summer crop, and under metal halide lights for the winter crop. Either production scenario was adequate for the plants used for the restaurant. The plants grown under the metal halide lights was the targeted result, as that was already attainable in the current situation.

The ultimate goal of this project is to identify ideal LED lights to use in an array in a large arrangement for producing high quality plants for commercial use.

The lights that were purchased for this project started with a 150watt LED array manufactured with the spectral configuration of

Color	Wave length	LED %
Red	630nm	40%
Far Red	660nm	60 %
Blue	460 nm	20 %
Yellow	610 nm	10%
Orange	615 nm	20 %

Interior Alaska experiences a magnificent change annually in day length from summer to winter. This change results in extreme long days or extreme short day periods, both conditions are not ideal for most commercial agricultural crops. The challenge of selecting a spectra for grow lights not new. There are many research programs throughout the world doing this very thing. What is unique with this project is the comprehensive study and analysis of LED light spectra as a supplemental light source and as a total light source for a large scale hydroponic crop.

Project results:
Prior to the LED system there was an annual energy consumption of 46080 kilowatts per year used only for lighting. This was an expense of $11,520.00. This is based upon a 16 hour day length, using 16 1000 watt lamps for 180 days. The lamps mounted in the ceiling were hung at 5 feet above the crop to maximize the illuminated footprint. The lamps have an annual replacement cost of $85.00 per year.
The total annual cost of lighting with existing fixtures is $12880.00 or $6.13 sqft.

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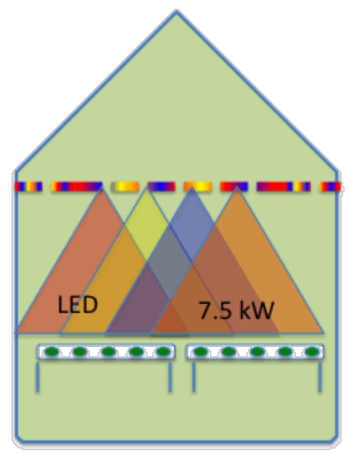
After the LED system installation an annual energy consumption of 21600 kilowatts per year was metered and used only for lighting. This was an expense of $5400.00. This is based upon a 16 hour day length, using a total LED array of 7560 (50 150watt LED Arrays) for 180 days. The lamps mounted in the ceiling were hung at 2 feet above the crop to maximize the illuminated footprint. The lamps have an annual replacement cost of $7.50 per year (the lamps have an estimated 7. 5 year life.
The total annual cost of lighting LED $8245.00 or $3.92 sqft.

The preliminary results have shown that it is possible to have adequate production under the LED as designed and installed. The lights that we have selected are preforming beyond or expectations.

The use of the LED have allowed us to better utilize our production space, increasing crop production as result of an even light distribution that is focused on the needs of the plant. Although the crop production is stable in time from seed to finish, the plant appears to be a little stronger, better branched, and less likely to bolt.



The annual saving of the production system in respect to energy costs is $6240.00 or nearly $3.00 per square foot. The annual savings in respect to equipment replacement and bulb maintenance is $1735.00 per year. A combined savings of $7985.00 All energy calculations are based on a $0.25kW cost.

As result of the improved lighting it was possible to increase productivity by 100 plants per week or 5200 plants a year. Production cost per plant prior to LED was average $0.75, production costs when using LED is average $0.42. Electrical cost per plant prior LED was $0.44, following LED and increased production is now $0.25 using the same production apparatus.

All plants were grown using standard NFT tough type recirculation system with water soluble fertilizer. Lettuce typed evaluated for this study were Nevada green, red and romaine. Seeds available from Johnny's Seed Company. In addition to the LED array purchased on this project. LED arrays were purchased and configured with the same spectral characteristics determined in this study were purchased and installed on the entire greenhouse lettuce production.

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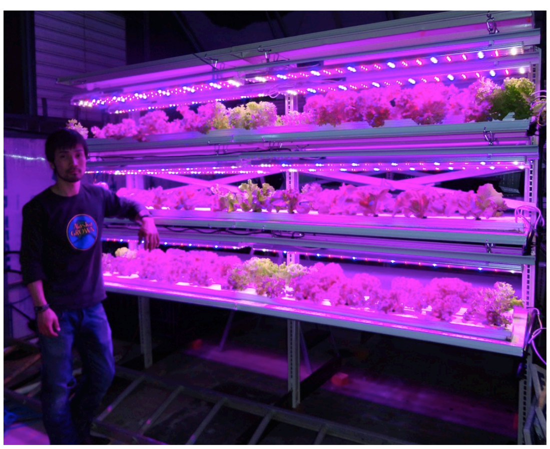
LED array installed in operation over lettuce crop.

24 LED arrays of 350-400 watt each are distributed horizontally over the lettuce production area spaced 24 inches on center and suspended 24 inches over the crop. The LED arrays are attached to a 20 foot long strut that is suspended from the greenhouse structure on chains. The LED arrays are suspended from the strut with small cable. The arrays are plugged into 120v outlets mounted on the strut. Each light circuit is controlled by a greenhouse controller from Link4Corp , Los Angeles, California model igrow 1400.

LED array over the crop.



LED array used in plant factory.
NFT lettuce system on shelves using LED array in winter production.

Financial

Total project..$30,076.20
State of Alaska $5000.00
Chena Hot Springs Energy (lighting and heat)...$26176.20
Welthink Electronic America, LED Lights as per State Contract $3900.00
Total project receipts $30076.20
Balance due State of Alaska 5000.00

All equipment is at Chena Hot Springs Resort in production and property of Chena Hot Springs.

The project was publically presented at

2011	Renewable Energy Fair at Chena Hot Springs Resort
2011-12	Daily greenhouse tours at Chena Hot Springs Resort, everyday 2pm and 4pm
2012	Alaska Vegetable Growers Conference

SOURCE OF FUNDS	AAIGFUNDS	MATCHING FUNDS	
LED GREENHOUSE LIGHTS	$5000 for 11 lights	Seeds Fertilizer	$2000
		Labor	$20,000
		Heat and Electricity	$7200
TOTAL COST	$5000		$29,200

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