SUPPLEMENTAL LIGHTING IN ALBERTA GREENHOUSES

Saeid Mobini, Ph.D.
Greenhouse Research Scientist
Greenhouse Section, CDC South

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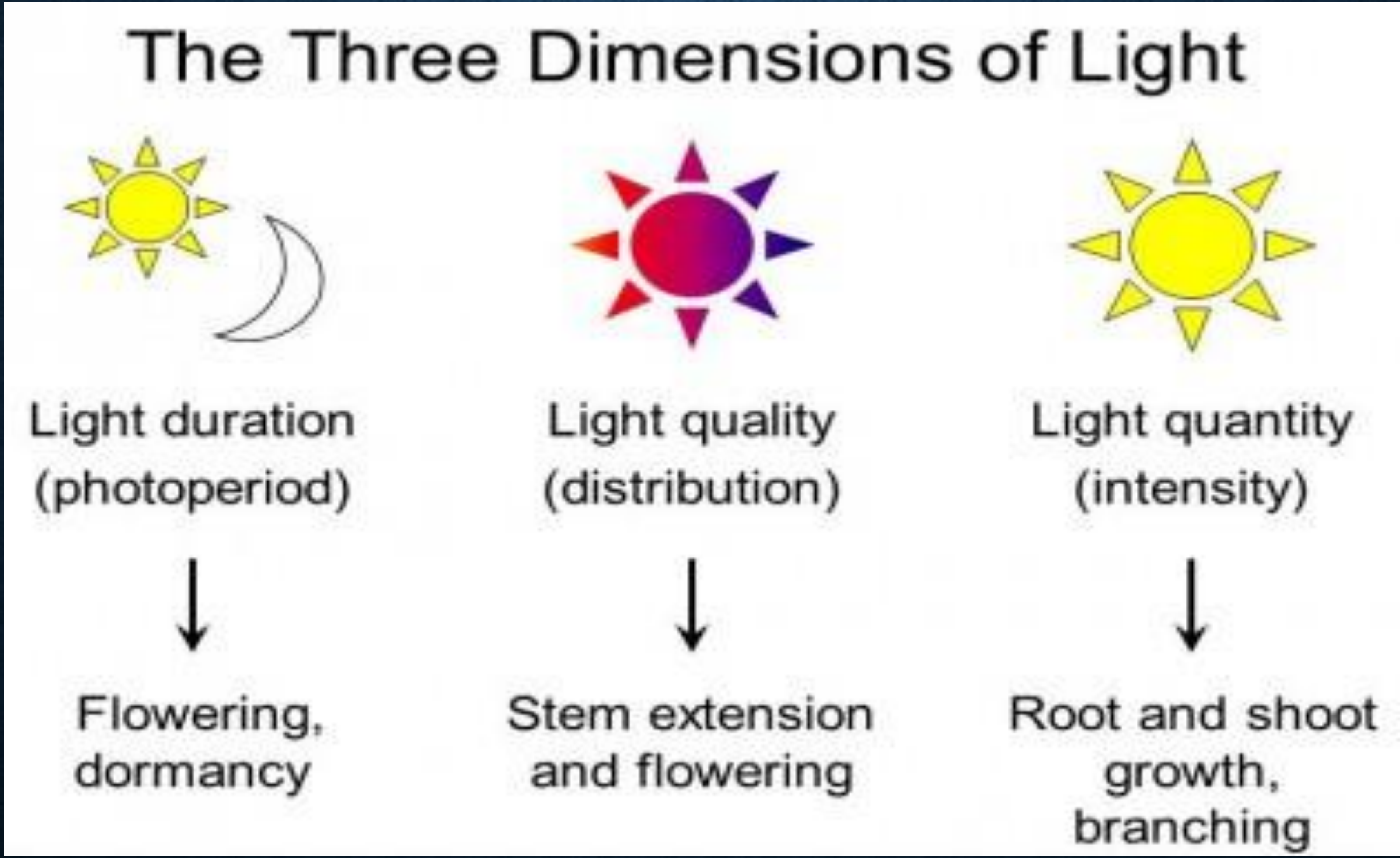
OUTLINE

- What is a light reaction in plants?
- What is supplemental light?
- Applications of supplemental lighting
- What is the appropriate lighting system for winter vegetable production?
- A path to the development and commercialization of lighting systems
- What are your desired results from this experiment?

LIGHT REACTION IN PLANT



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SUPPLEMENTAL LIGHT

- Provides additional energy for plant when there is a deficiency of solar radiation (light).

- There is a variety of supplemental lighting sources:
  - **HPS** (High Pressure Sodium)
  - **LED** (high intensity Light-Emitting Diode)
  - **Intra-canopy LED**

WHY SUPPLEMENTAL LIGHTING??

- High success rate throughout the **winter crop production**
- **Sustainable year round** crop production
- Control your plant environment (**healthier plants**)
- Supplemental lighting: even in sunny winters of Southwest, US!!!

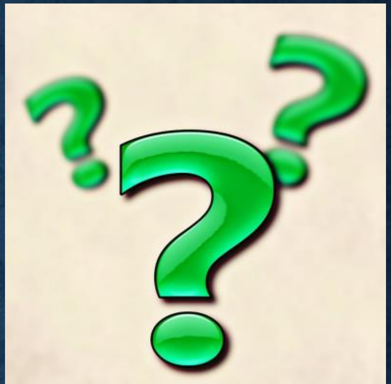
GH tomato production in the US

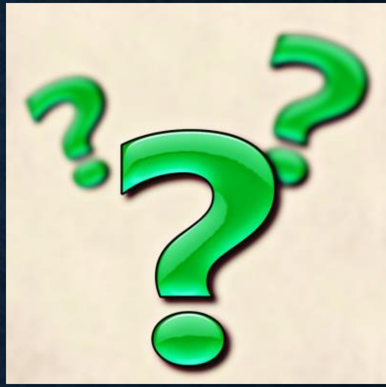
APPROPRIATE LIGHTING FOR WINTER CROPS

LED Tips:

- Place your LED lamp close to plant surface; **SAVE ENERGY!**
- Suitable for use in **intra-lighting** applications.
- Direct lighting into the inner canopy of crop stands, **higher efficiency of irradiation**.
- Stay on pace with the growth stages of high-wire crop production (multi LEDs layers)!

GAPS IN THE KNOWLEDGE





- New intra-canopy LED technology; (advantages/disadvantages)
- Ready for commercial production???
- Or more improvement???
- LED lamps, a potential alternative to the current (HPS) supplemental lighting technology?

HIGH INTENSITY LIGHT-EMITTING DIODE (LED) LAMPS

✓ LED characteristics? TYPES!!!

- Solid state; which is flexible, for different designs (light quality, shape, and the distribution of light).

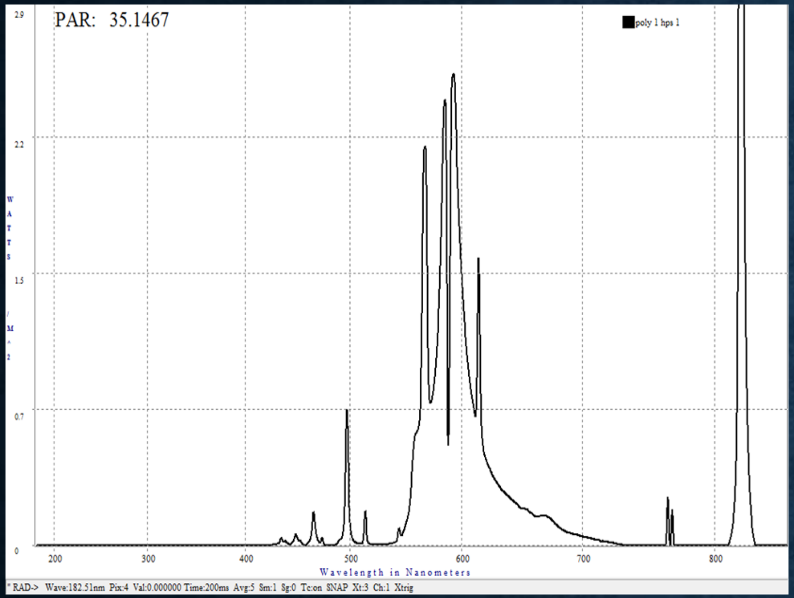
✓ More light from less electricity!

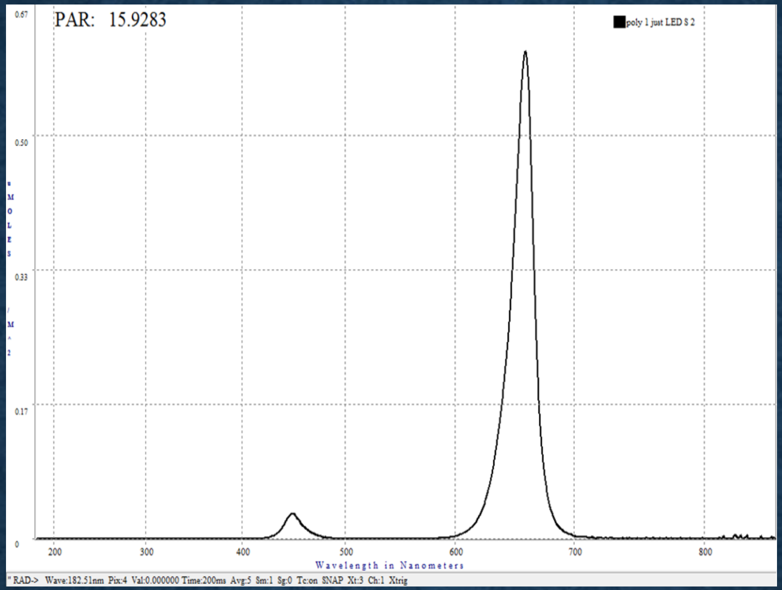
✓Useful for intra-canopy lighting; low operating temperature.

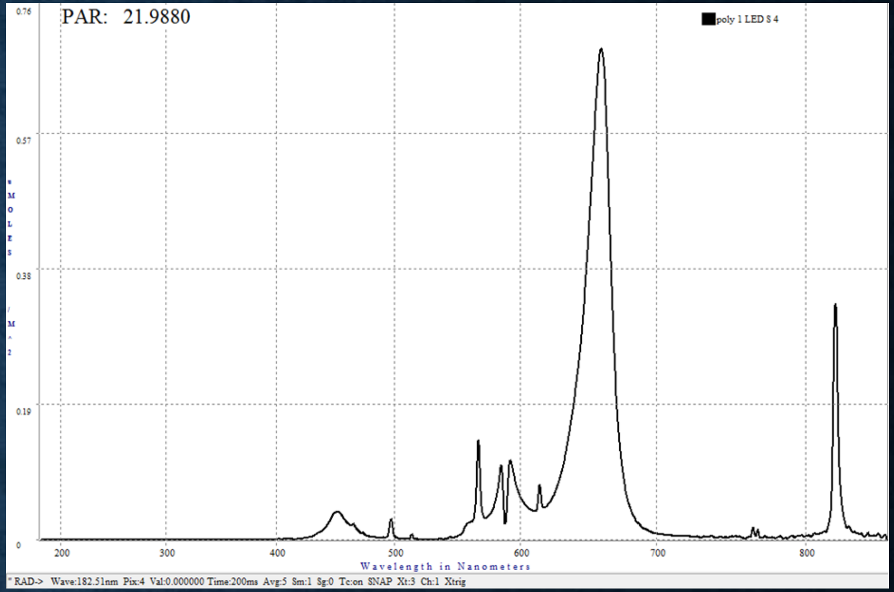
✓Huge investment; robust, very long-lived lights, cost effective!

✓Would this be effective for all plants?

LIGHT QUALITY of LED and HPS in OUR STATION
(POLY 1 in CDC SOUTH)



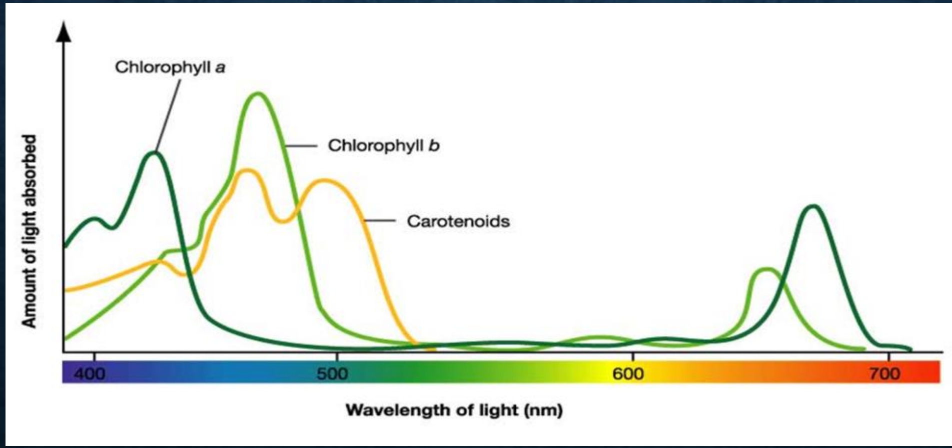




HPS

Intra-Canopy-LED

HPS plus Intra-Canopy-LED

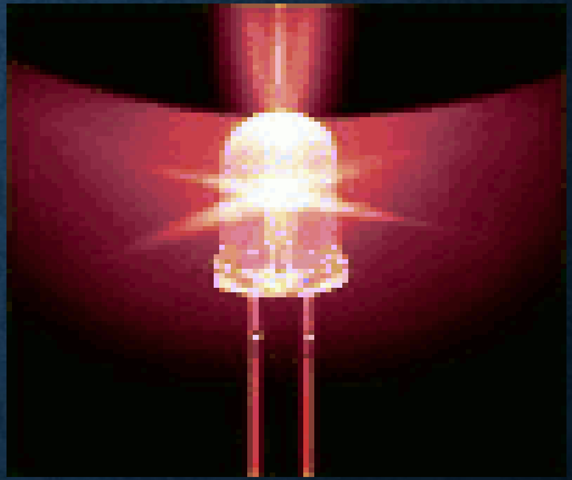


The action spectrum of photosynthesis: 400-500 & 650-700 nm.

METRICS FOR PLANT LIGHTING MEASUREMENT

Photosynthetically Active Radiation

(PAR; 400-700 nm)



Photosynthetic Photon Flux

(PPF; $\mu mol \cdot m^{-2} \cdot s^{-1}$)

Daily Light Integral

(DLI; $mol \cdot m^{-2} \cdot d^{-1}$)

DAILY LIGHT INTEGRALS (DLI)

Effect of light is not cumulative!!!

- DLI provided by supplemental lighting will fill the deficiency of solar radiation (make a daily balanced) as well as the specific plant light requirements.

WHY SHOULD I MEASURE DLI IN MY GREENHOUSE?

- DLI affects plant quantity, photosynthetic rate and plant growth (biomass, yield)
- DLI a key factor for:
  - Adjust plant density (the most significant factor)
  - Shade curtains (deploy or stow)
  - Whitewash (apply or remove)
  - Hanging basket density (increase or decrease)

DO I NEED SUPPLEMENTAL LIGHTING OR NOT? IF NEEDED, HOW MANY MOL $M^{-2}D^{-1}$?

18-h light with >185 µmol m^{-2} s^{-1} PPF if available over the canopy (DLI > 12 mole $m^{-2}d^{-1}$)

What is the sufficient DLI for my plant?

Mini and Max DLI examples form the literature (Runkle 2011)**:**

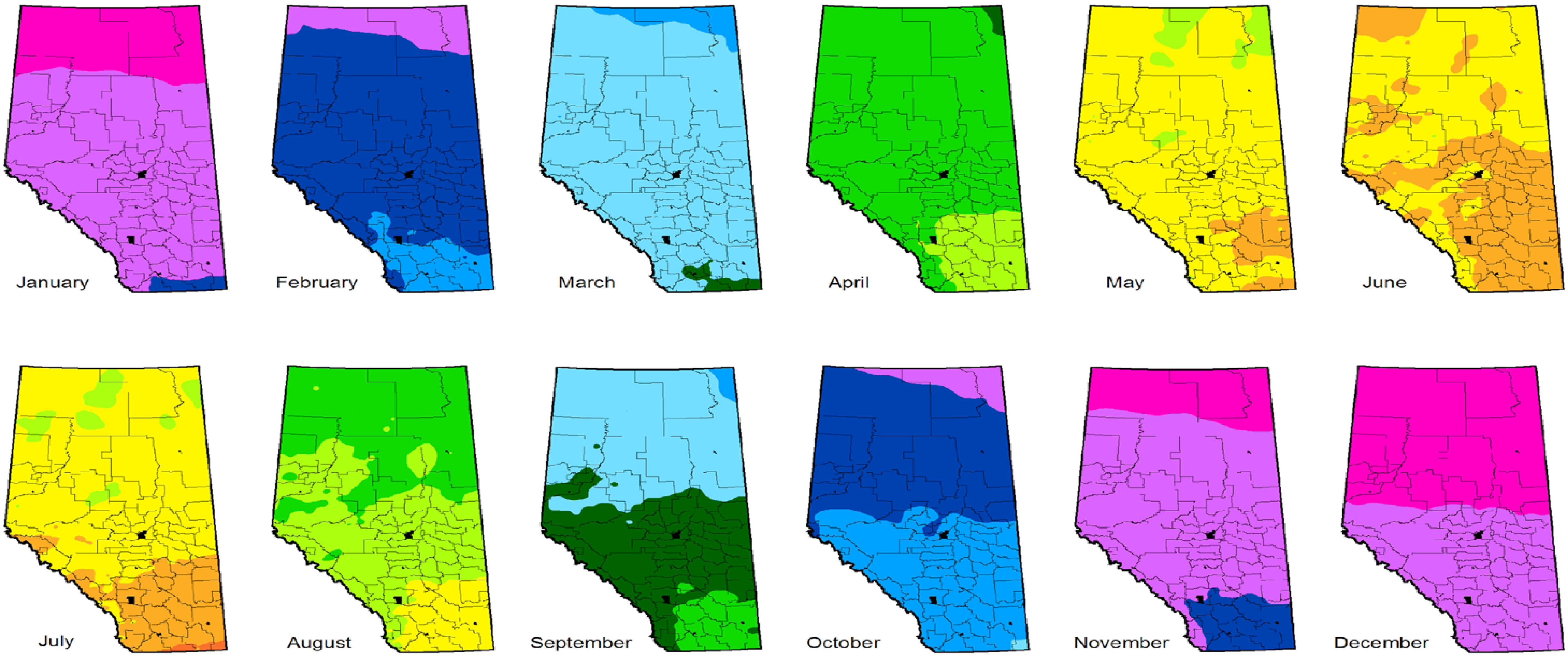
- DLI =12 moles $m^{-2}d^{-1}$: the minimum inside GH target light level to **grow fruit vegetables.**

  DLI =10 moles $m^{-2}d^{-1}$: the minimum inside GH target light level to **grow leafy vegetables.**

  DLI = 2-4 moles $m^{-2}d^{-1}$ average in Netherlands during the winter time within a glass greenhouse (assuming 50% glazing reduction).

- The maximum DLI we receive outdoors is about 60 mol m^{-2} d^{-1} on a cloudless day in the summer.

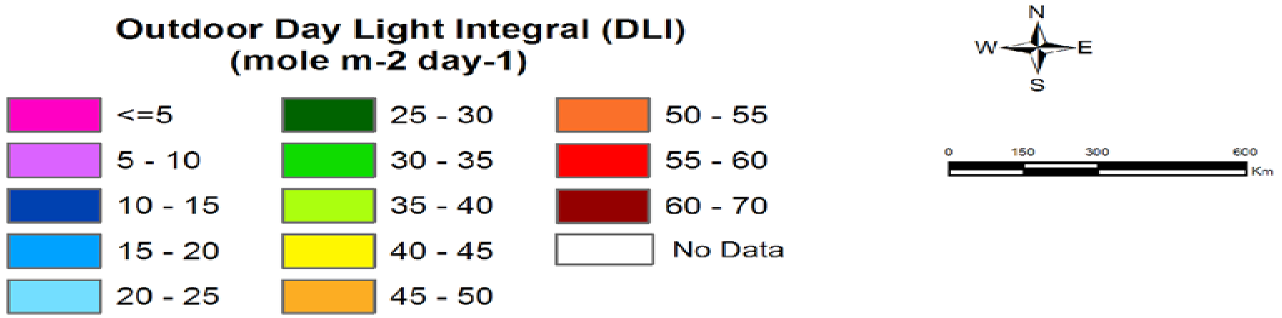
- On a dark winter day in the northern part of Alberta, the outdoor DLI could be less than 5 mol m-^{2}d^{-1}



Outdoor Daily Light Integral (DLI)

1986 to 2015 monthly average

DLI computation was based on daily estimated solar radiation using the 1985 Hargreaves equation that showed good agreement with measured solar radiation data across the province

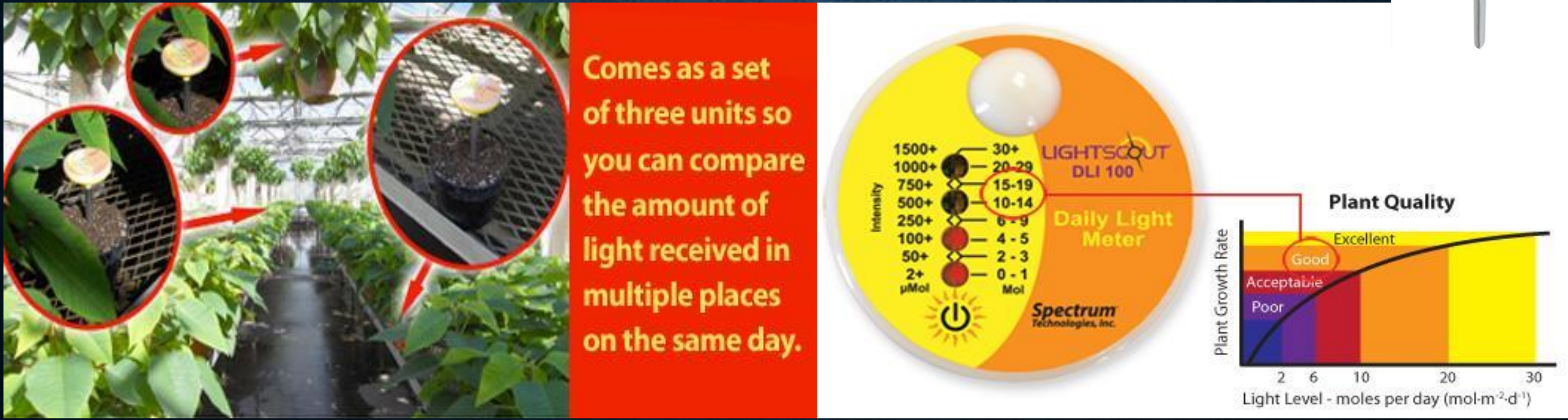


Compiled by Alberta Agriculture and Forestry,
Environmental Stewardship Branch,
Engineering and Climate Service
Created on June 17, 2016

HOW DO I MEASURE DLI IN MY GREENHOUSE?

- Using DLI meter:

Easiest way to get an estimate of existing light quantity close by my plants.



LIGHT PROJECT GOALS (in progress):

- **Adjust LED light quality and quantity** for commercial varieties of cucumbers and tomatoes in Alberta greenhouses.
- **Compare LED** with the conventional HPS lighting (side-by-side).
- Test new fixture designs (**ICL**) and application methods.
- Illustrate the effect of light source on **energy use efficiency** and **yield improvements**.
- Determine the effect of lighting treatments on **leaves' edema and fruit quality**.
- Compare the **cost-effectiveness** of ICL-LEDs with over head lighting (OHL)-HPS.

Material and Methods

RCBD design (4 replication)

4 treatments (Sunlight; HPS; LEDs in two layers; HPS + LEDs in two layers)

HPS (600 W $m^{-2}h^{-1}$),

LED (130 W $m^{-2}h^{-1}$)

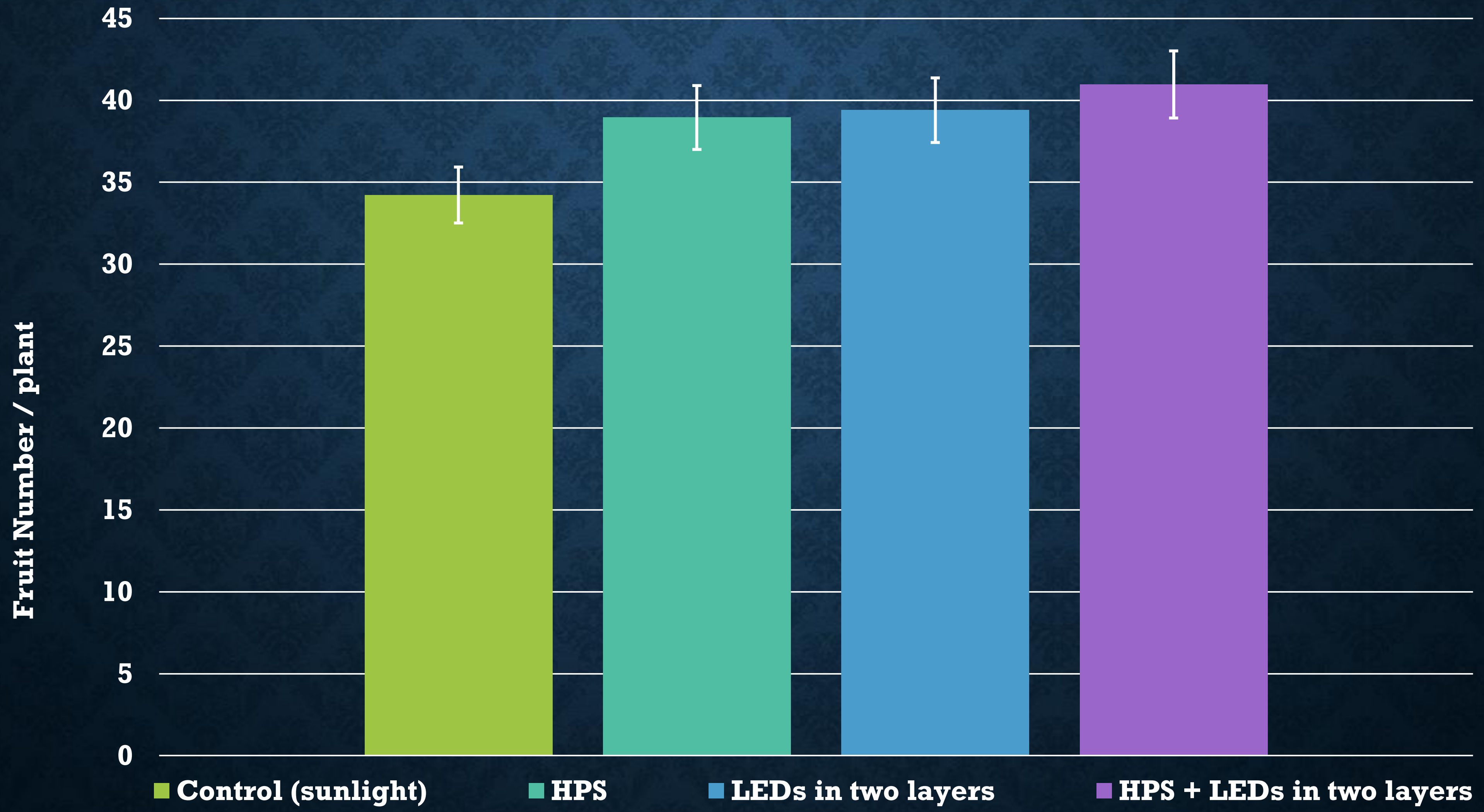
Cucumber (var. BonBon)

(Sept – Dec & Jan – April)

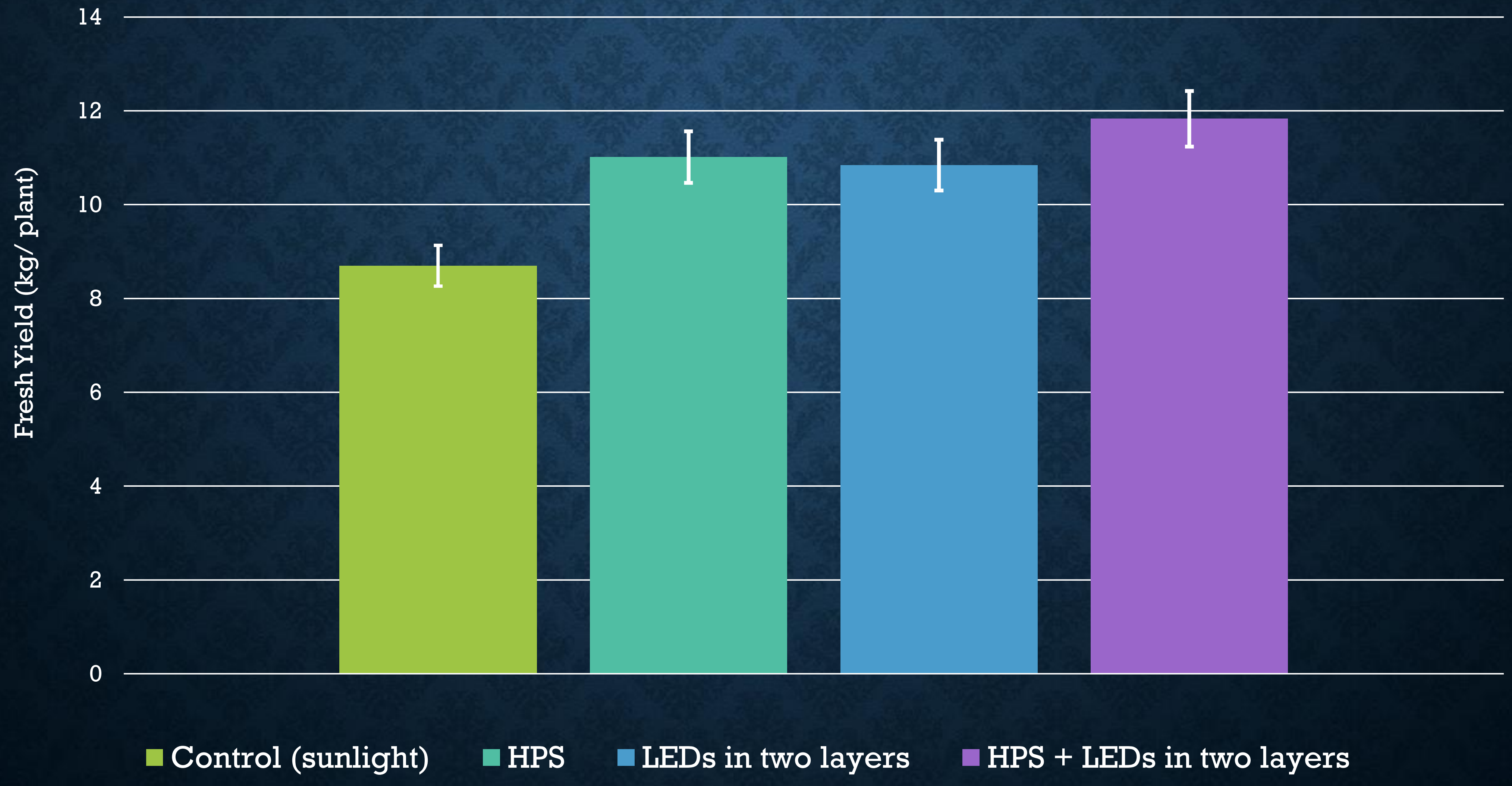
18-hours supplemental lighting photo-period

Shut down light over 300 (**save energy**)

CUCUMBER (*VAR.* BONBON) RESPONSES IN FRUIT NUMBERS UNDER DIFFERENT LIGHTING TREATMENTS



CUCUMBER (*VAR.* BONBON) RESPONSES IN FRUIT YIELD UNDER DIFFERENT LIGHTING TREATMENTS



ENERGY CONSUMPTION

Treatment	No light/ exp. unit	Lamp number/m^2	Input power density (W/m^2)
HPS	4	0.2	$600 \times 0.2 = 120$
Two layers of ICL-LEDs	10	0.5	$130 \times 0.5 = 65$
HPS + Two layers of ICL-LEDs	4 + 10	0.2 + 0.5	120 + 65 = 185

- Lighting sources are HPS (600 W $m^{-2}h^{-1}$) and LED (130 W $m^{-2}h^{-1}$)
- 20 m^2 in each experimental unit
- Turn - ON threshold 300 W/m^2
- Photoperiod 16 to 18 h

Treatments	Measured fixture light intensity in canopy [A]	Energy used in the experiment (Watts/m^2)	Yield/Electricity(kg/kWh)% [B]
HPS	49.7	120	32.9
Two layers of ICL-LEDs	43.1	65	59.9
HPS + Two layers of ICL-LEDs	68.3	185	22.9
A . µmol $m^{-2} \cdot s^{-1}$ B. With average of 6 hours lighting per day			

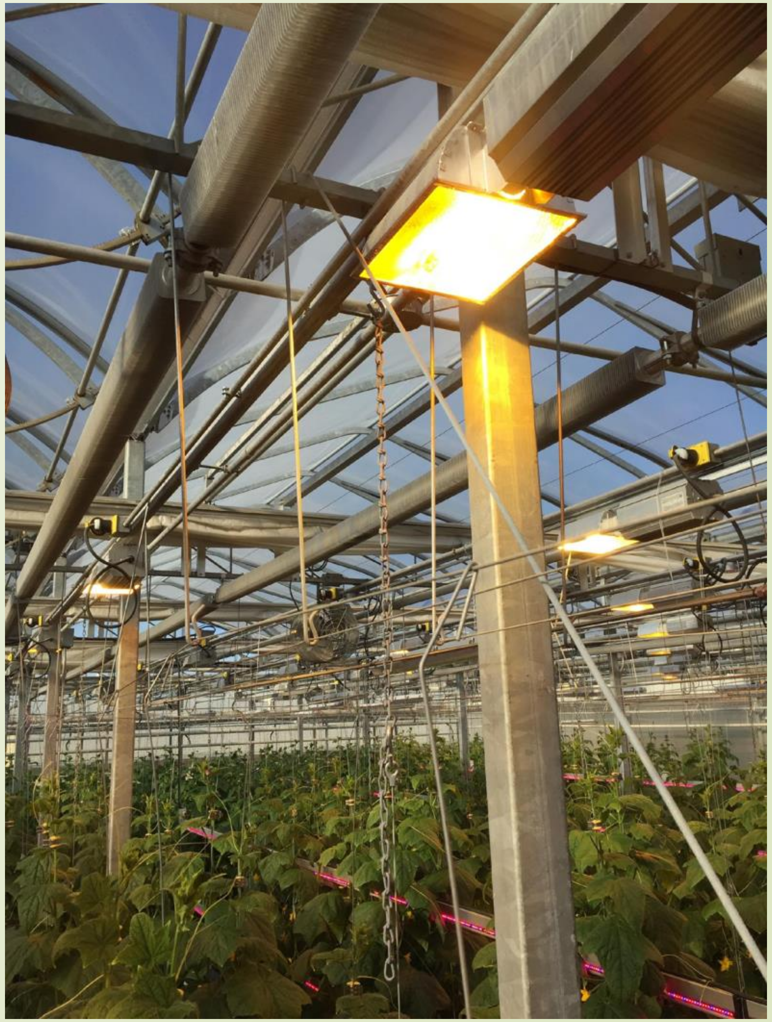
Side effects of intra-canopy lighting

Leaves can block LED irradiance distribution

Leaves can be photo-bleaching by high light intensity close by LED arrays

Side-by-side comparison ICL-LED with the conventional HPS lighting

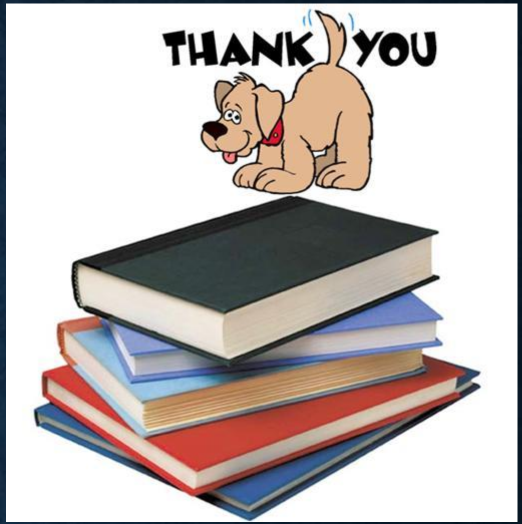
Lots of sunlight barriers by the greenhouse structure



TOWARDS THE DEVELOPMENT AND COMMERCIALIZATION OF LIGHTING SYSTEMS

- Focus on intra-canopy lighting LED systems **at commercial level.**
- Assessing the efficiency of this new technology (ICL-LED vs. OHL-HPS) and demonstrating its **feasibility and potential** in crop productivity improvement.
- Address **challenges facing greenhouse growers using HPS and LEDs** in Alberta.
- Providing fundamental information for future business decisions such as **investment, commercialization, and strategic direction** on greenhouse lighting system in Alberta.

ACKNOWLEDGMENT:



My team members:

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- Zengguang Guang Pan and Shannon Petersen (CDC South)

My collaborator:

- Daniel Itenfisu (Engineering and Climate Services Section)

My colleagues:

- John Zhang
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- Tommy Li

Growing Forward 2
A federal-provincial-territorial initiative