Plant Productivity in Response to LEDs Light Quality

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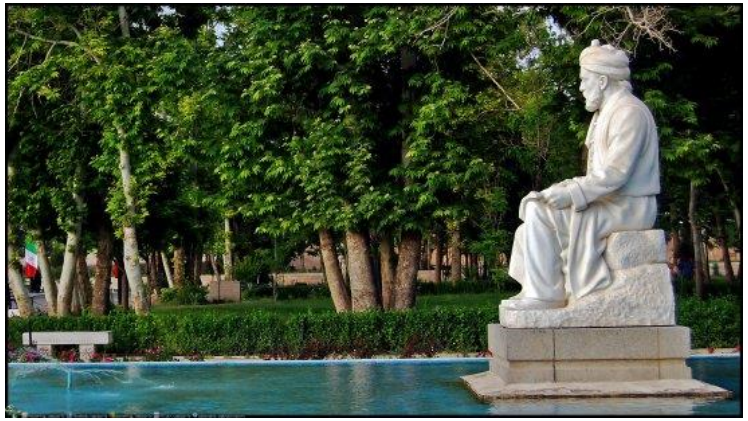
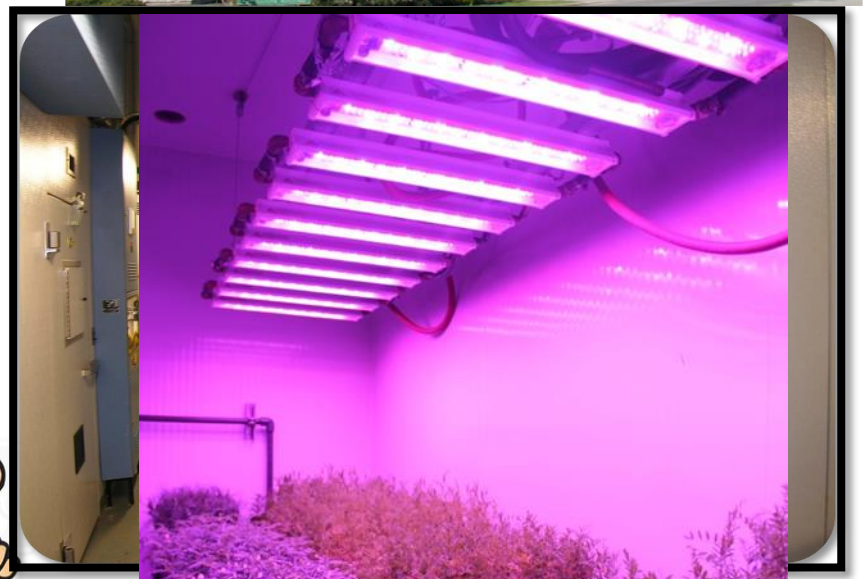
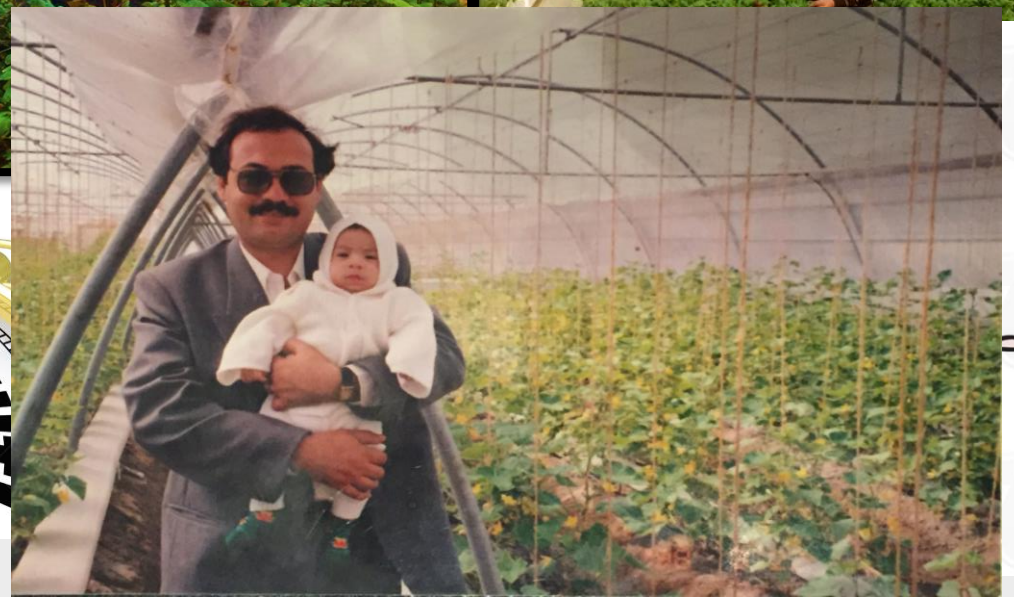
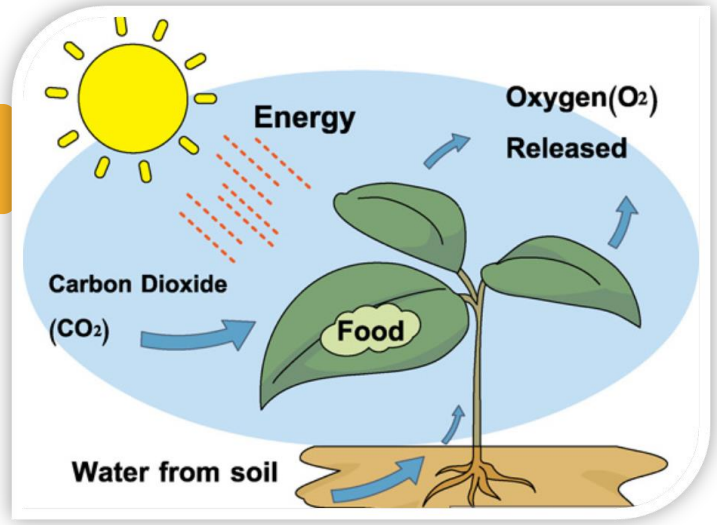


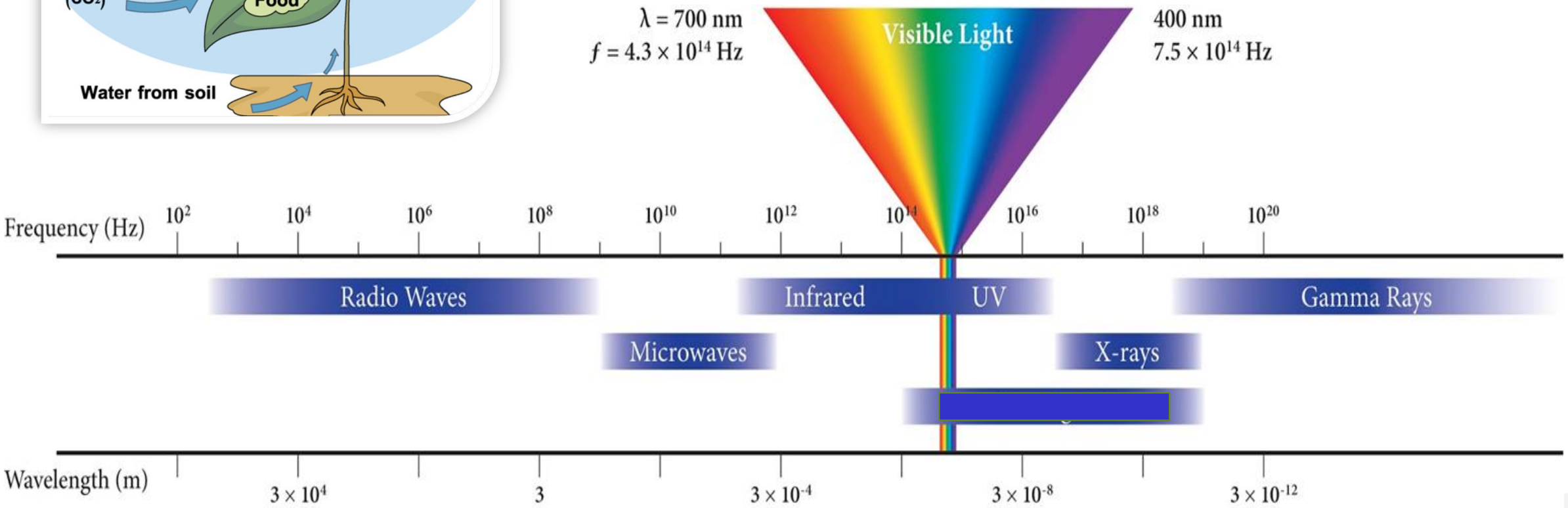
Saeid since 1998







Electromagnetic Spectrum



PAR (photosynthetically active radiation) spectrum 400-700 nm

Photometric Method

- Based on the sensitivity of the human eye (**not plant**) to detect electromagnetic radiation
- Very subjective
- Standard Unit = 1 foot candle (ftc)
  - Amount of light given off from 1 candle at a distance of 1 foot

Radiometric Method

- **Measures of electromagnetic radiation in terms of total energy**
- Standard Unit = $W.m^{-2}$
- **Wavelengths function very differently on plant growth and development.**

Quantum Method

- **Measure of Photosynthetic Photon Flux (PPF) of 400-700nm in area (density) called PPFD**

- **Not measuring λ of entire spectrum, it is measuring the amount of photosynthetic light**
- Standard Unit = mol (6.02 x 10^{23}) photons = µmol (6.02 x 10^{17}) photons/m^2.s
- **Regular way to measure light in the chambers /greenhouse because plants are "counting" photons that they absorb.**

» **Disadvantage**

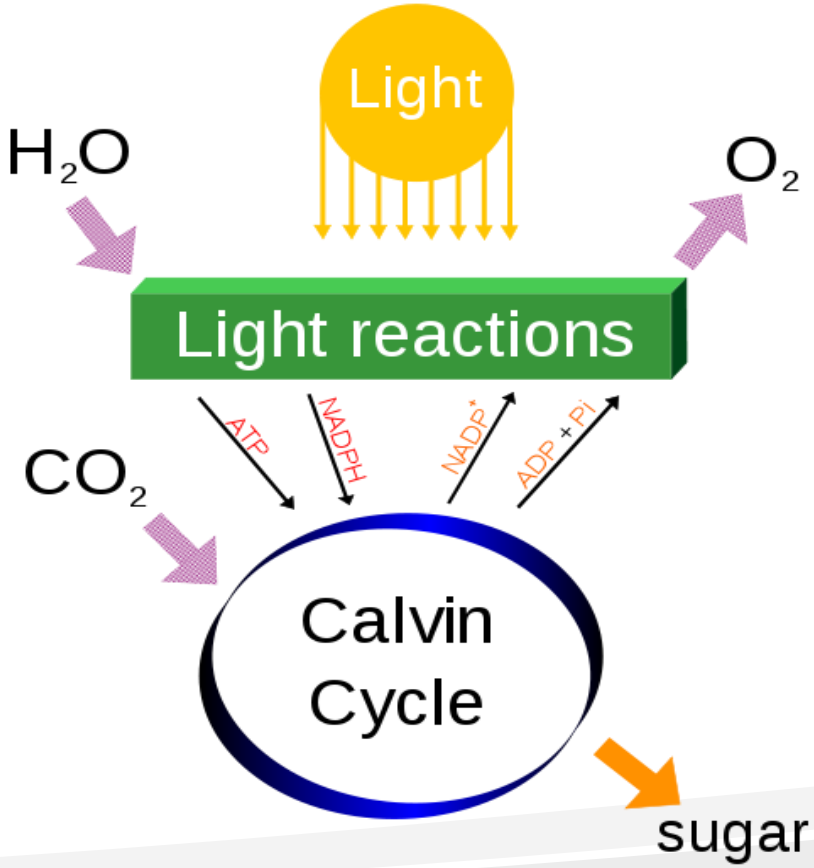
We are not able to measure the intensity of light at a particular wave length.

Light and Plant Growth

How much light is required for my plant photosynthesis and the best yield?

- **Quantity** (Intensity)
  - Photosynthesis e.g. biomass production
- **Quality** (Wavelength – Photoreceptors)
  - Photo-morphogenesis

  e.g. stem elongation, & flower induction
- **Duration**
  - Photoperiodism e.g. dormancy, flowering



The **pros** and **cons** of **New LED technology!**

Ready for commercial use???

Or needs more consideration???

Do LED lamps have the quality to meet your crop requirement?

LED characteristics?
LED tips !!

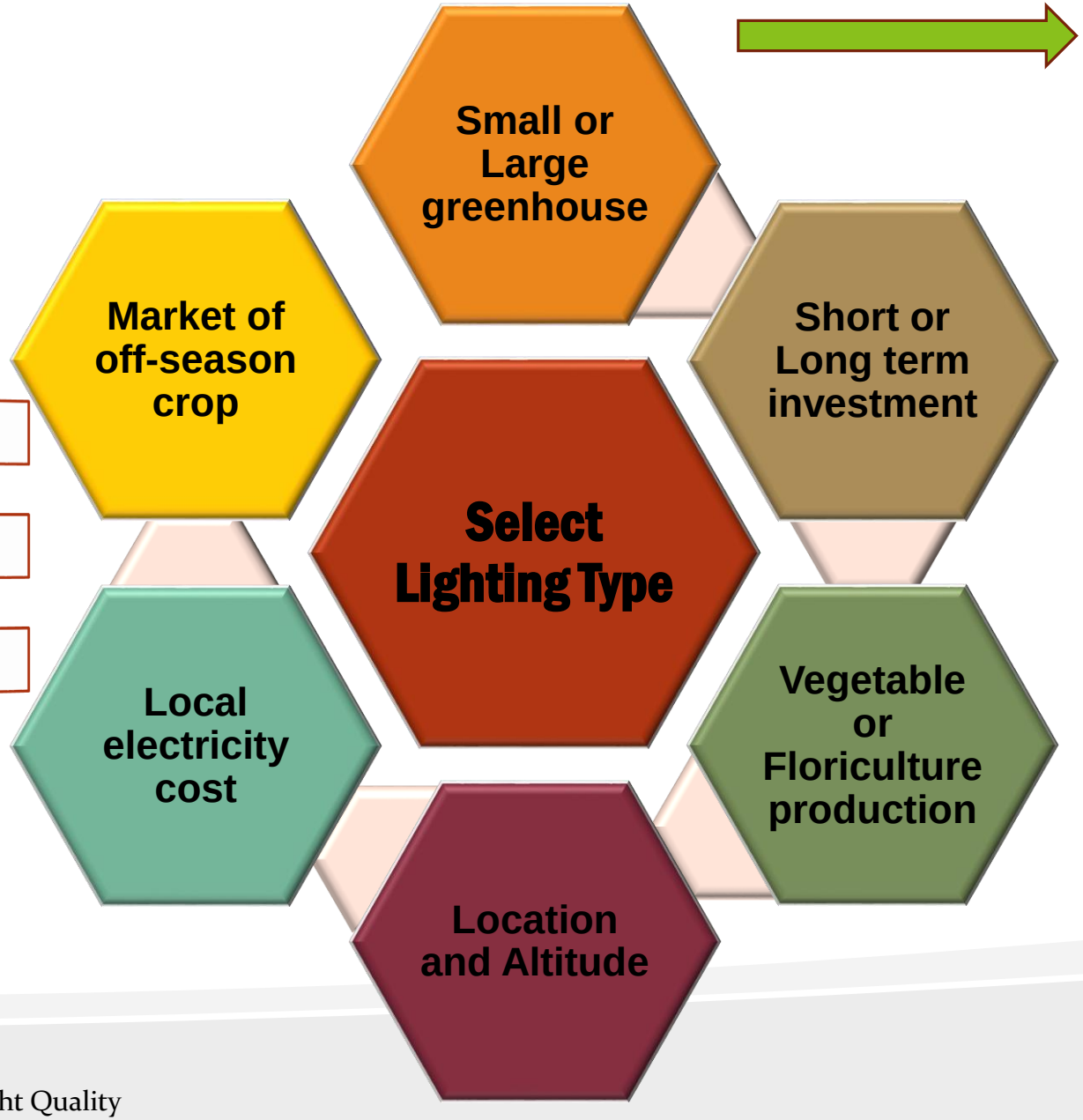
Which ones works for me better?

Select the right LED lamps:

Higher energy efficiency to convert electricity to the photons (e.g. HPS 1.58 vs. LED 2.6 µmols/Joule which is based on current technology and can be even improved to 3.0)

- Narrow bands of spectrum and their ratio
- Tunable and dimmable
- Provide specific wavelength for photosynthesis, photoperiod, morphology, and second metabolites

Light Fixture Specification:



- Shading of structure
- Height of fixture
- Cooling system

- Each crop needs specific spectrum
- DLI requirement is different
- Economic analysis required

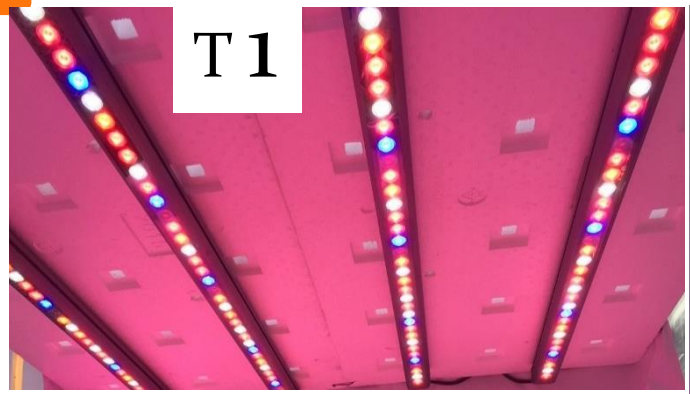
- More capital in LEDs
- No data available for LEDs for 20 y

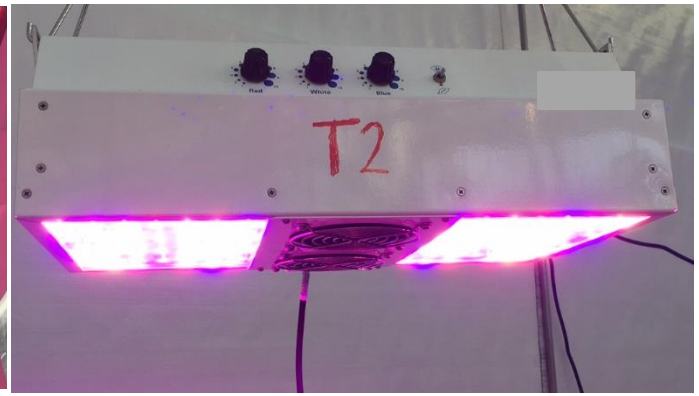
- Uniformity of PPF
- Wide spaced bench
- Narrow and tall rows

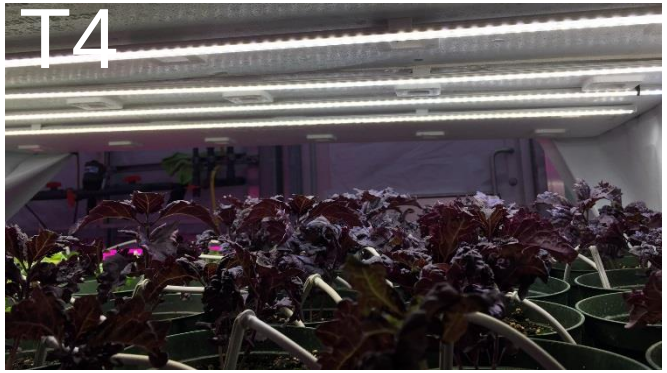
Materials & Methods

- Basil Green (Holy Basil, HR1023) and Red (Kitghen Blend, HR1011)
- Seeded on Dec 2, transplanted into 300 pots on Dec 16, harvested on Jan 20 and Feb 21, 2017.
- Growth condition: EC: 750-950 μs/cm, pH: 5.8-6.1; Temp: 23/19^{o}C day/night temperature; RH 40-60%;
- All plant kept in **equal light intensity** of PPFD=180 μmol.m^{-2}.s^{-1} **and photoperiod** (20 h/d) with plant density 44.4 plant.m^{-2}, using potting soil in half gallon pot and feed by 20-20-20 fertilizer 3 - 4 times a day.

LED light quality comparison among various LED sources in horticulture industry

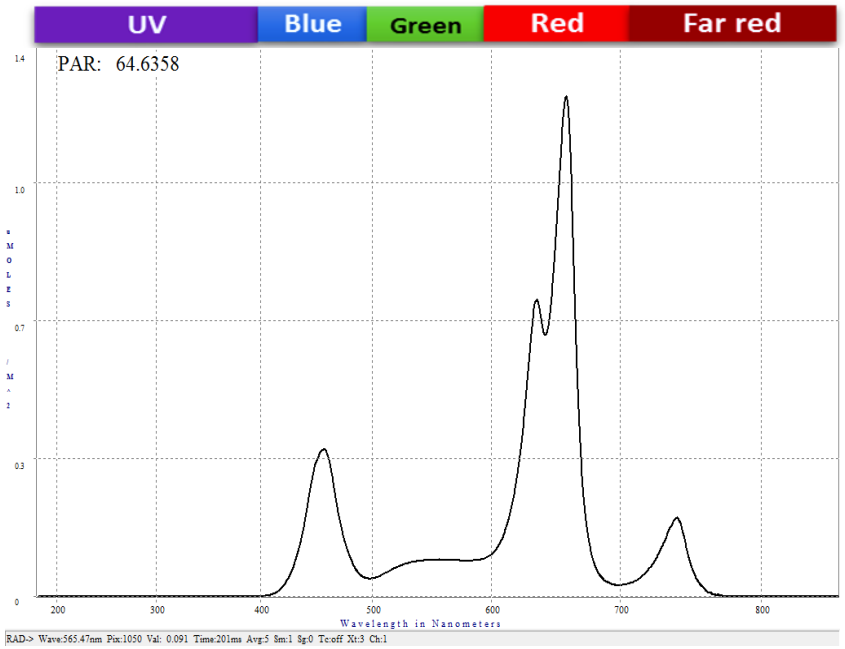




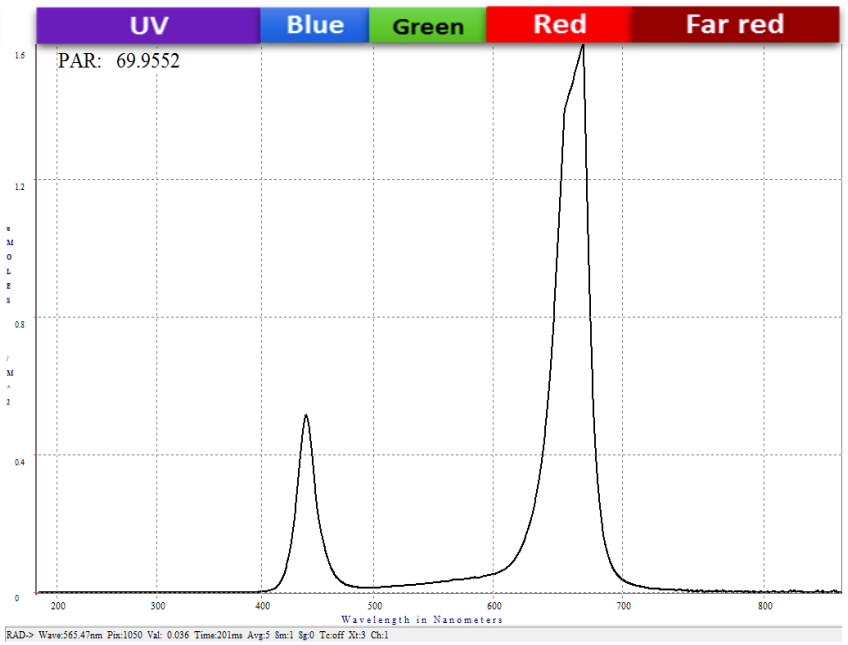


Comparison of Light Spectrum Among LEDs

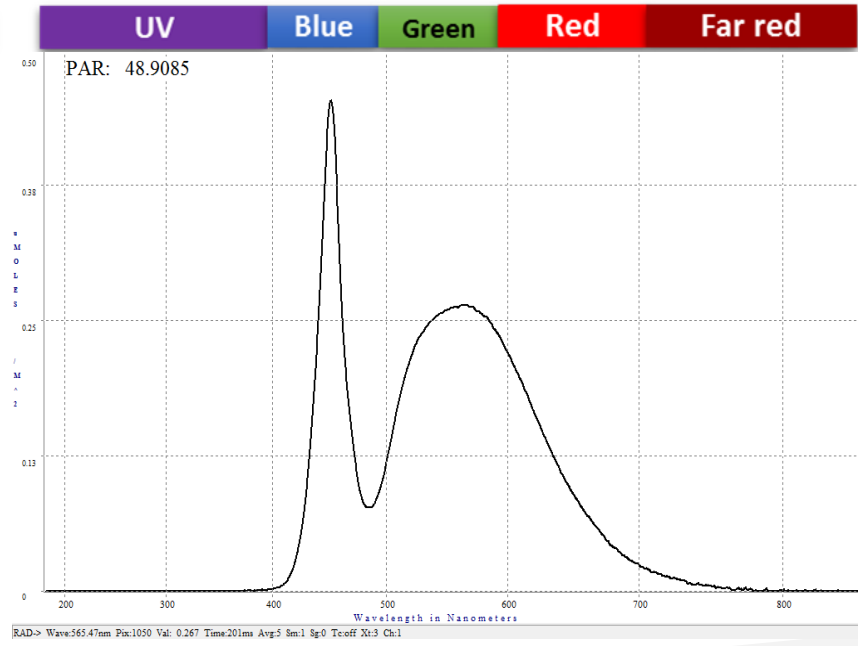
T1



T2

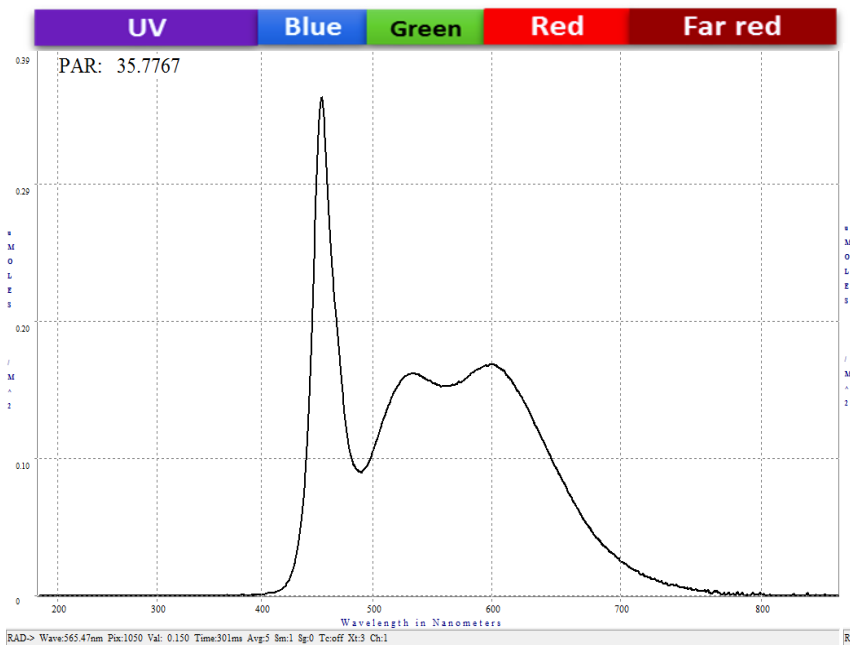


T3

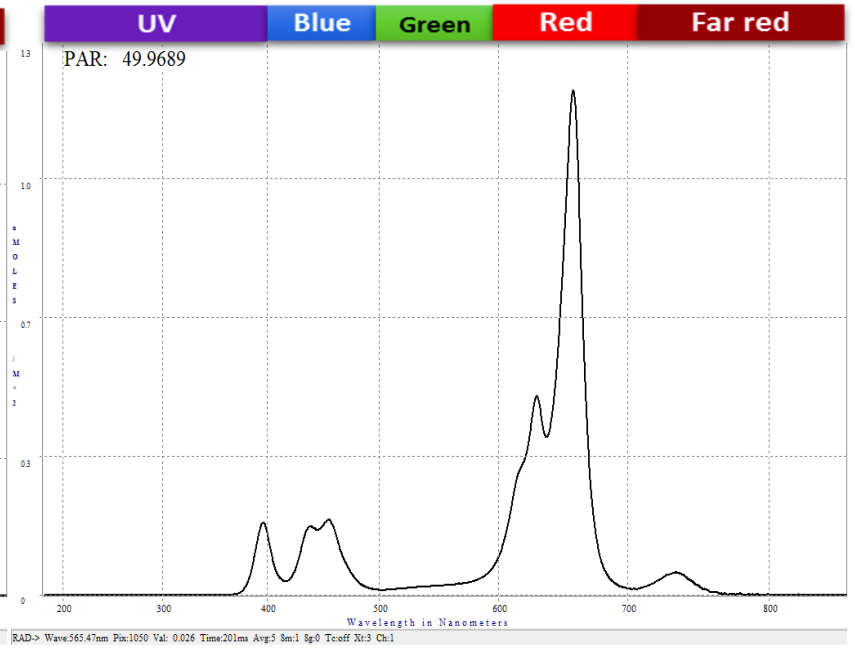


Comparison of Light Spectrum Among LEDs

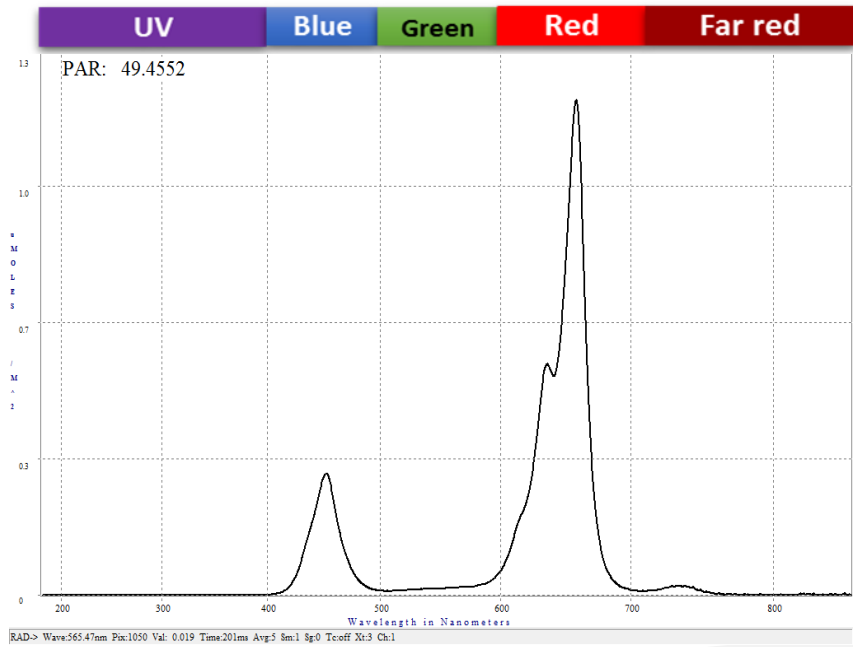
T4



T5



T6

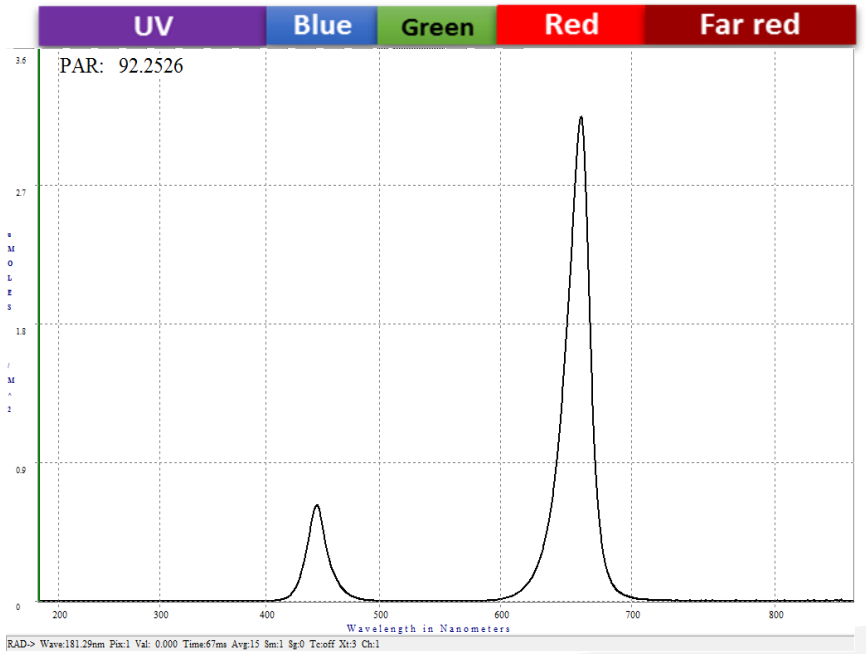


Light Spectrum Among LEDs

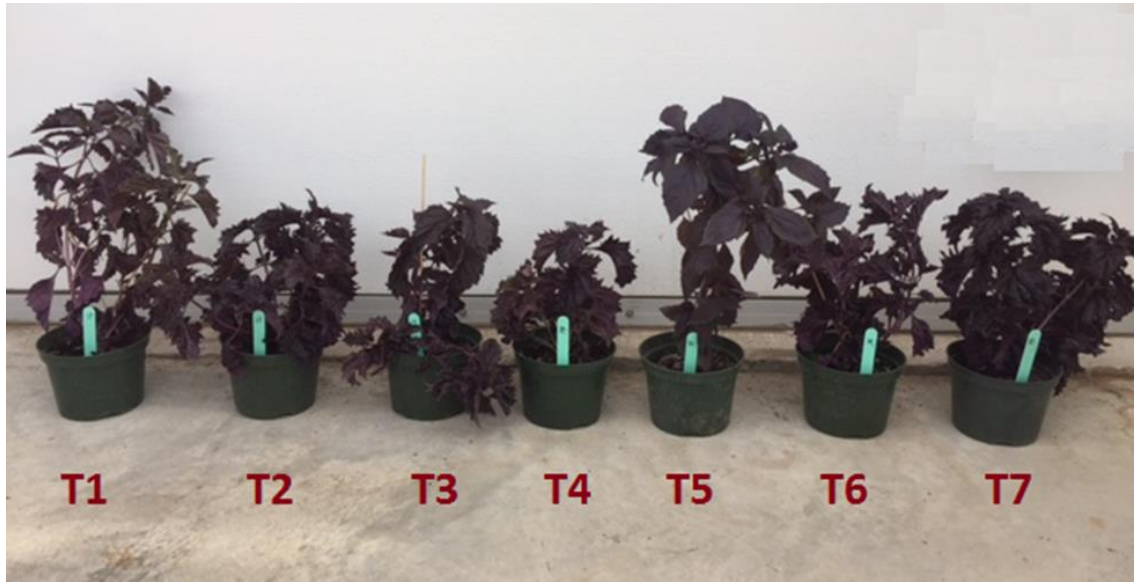
We compered:

T7

- Whole PAR spectrum
- Blue + Red
- Blue + Green + Red
- Blue + Green + Red + Far red (low)
- Blue + Green + Red + Far red (high)

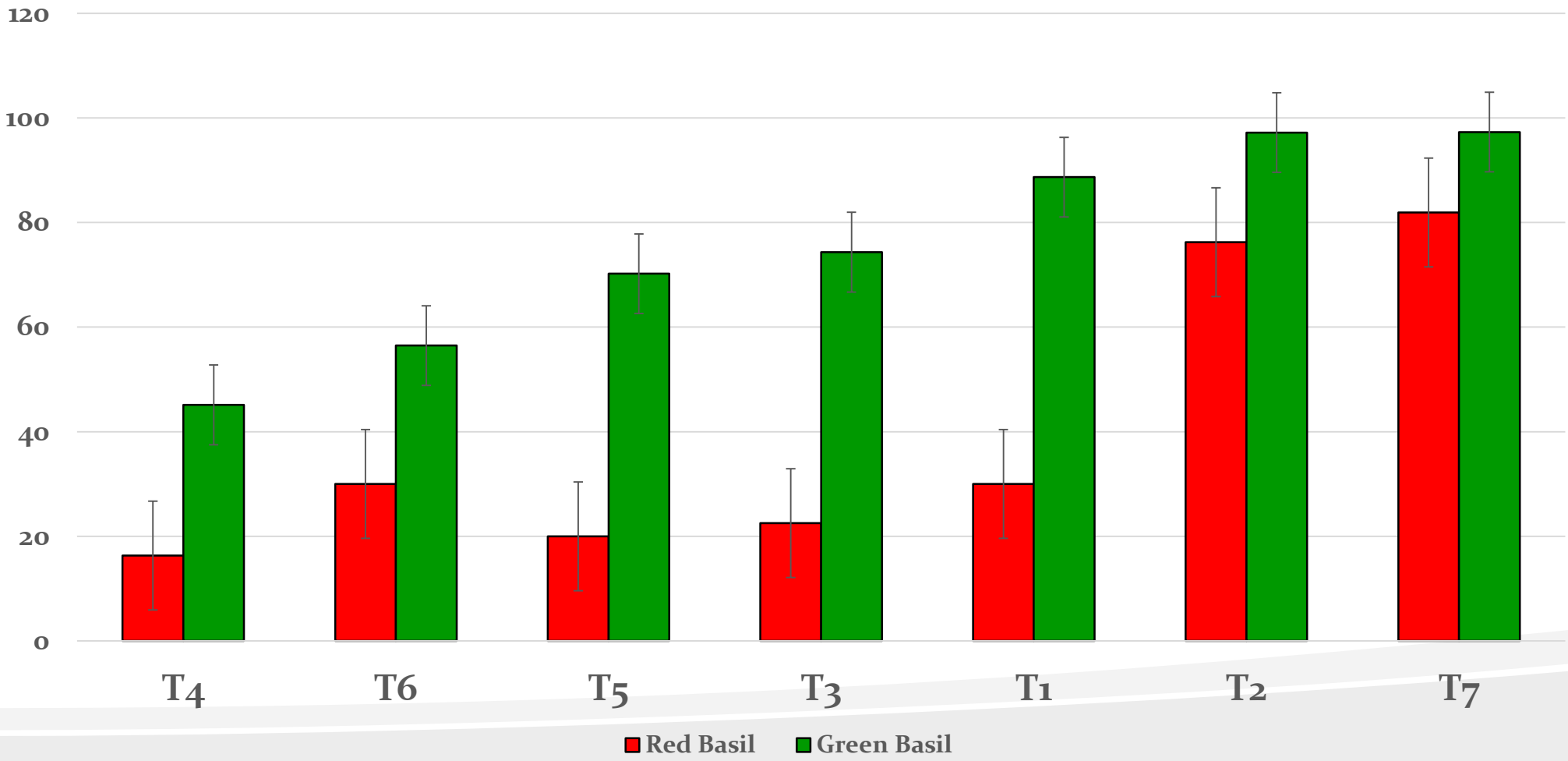


Result:

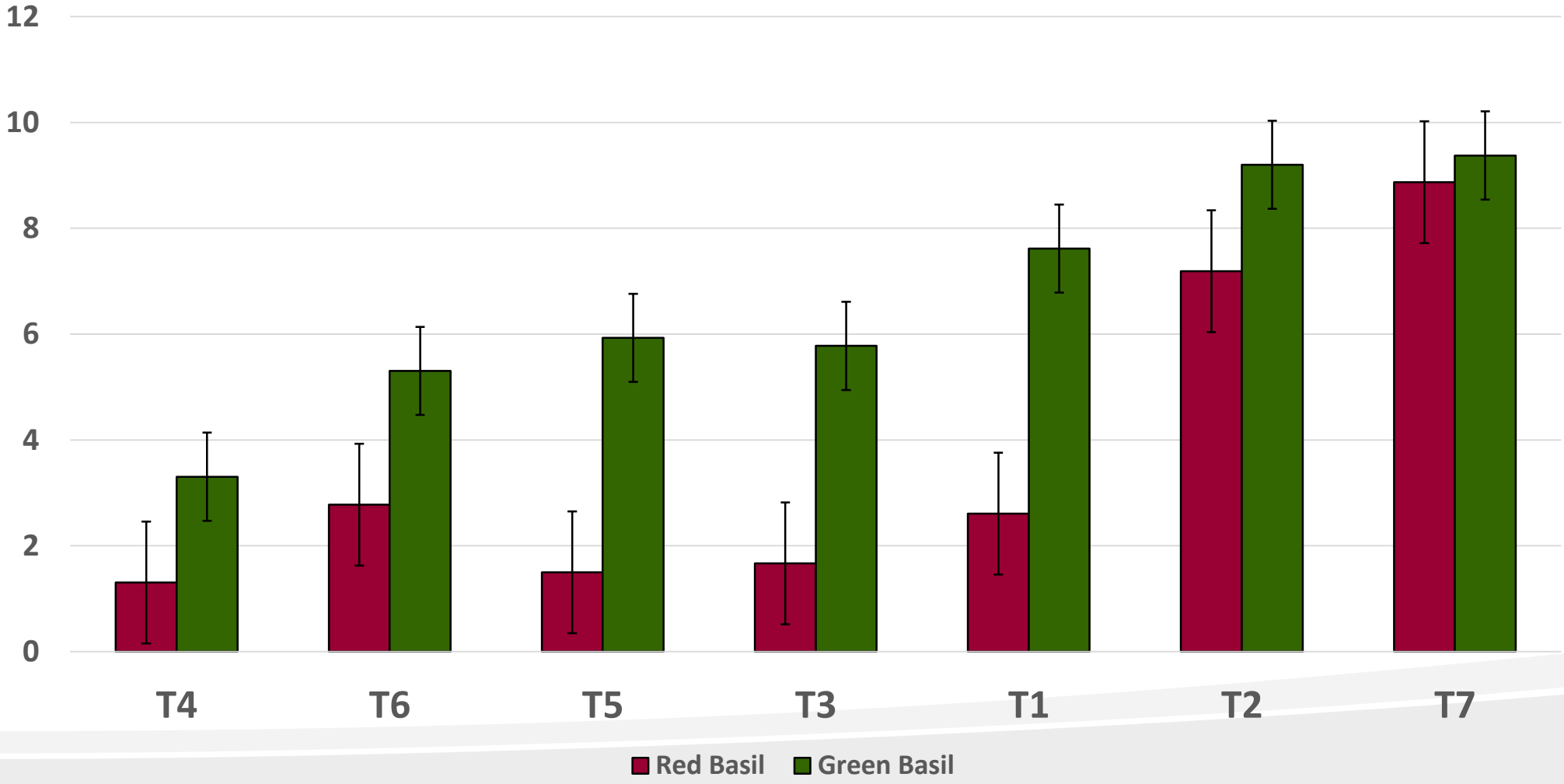


Side by side comparison of green and red basil growth condition under different LED sources with the same light intensity.

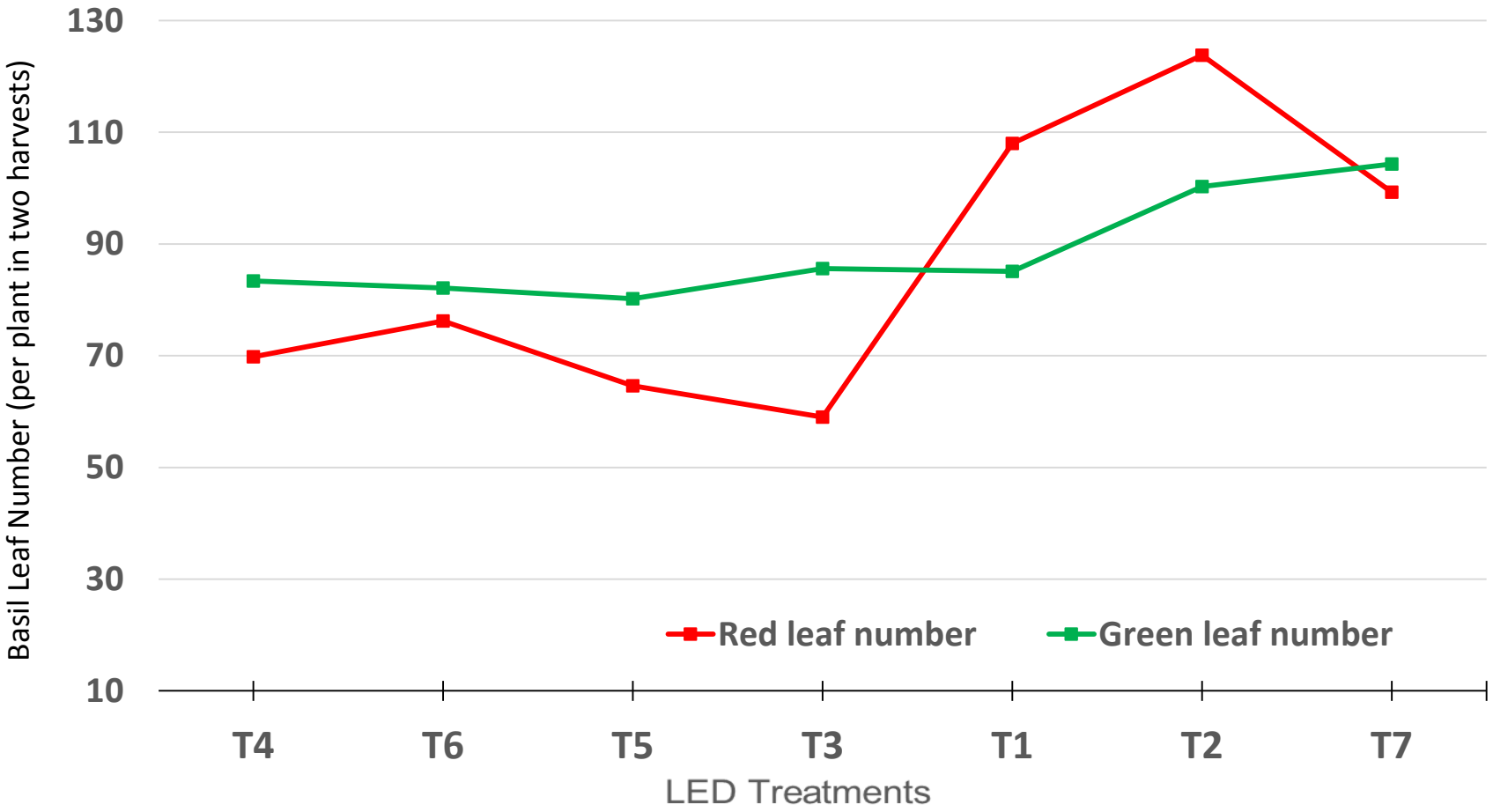
Fresh weight of Green and Red Basils under different LEDs (g/plant)

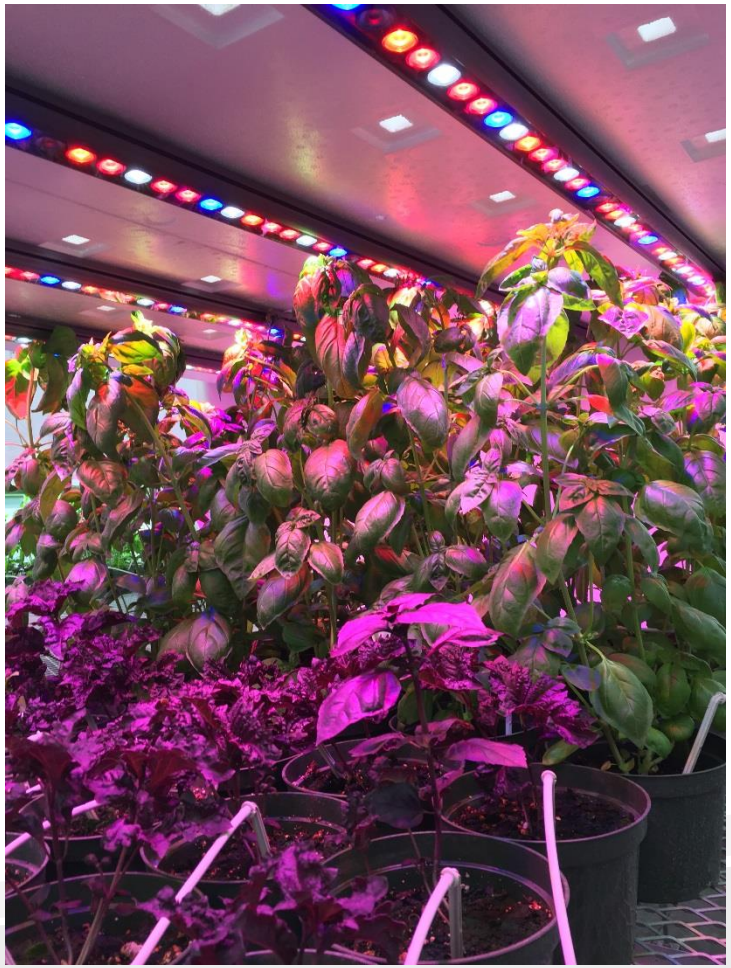


Dry weight of Green (*var.* Holy Basil) and Red (*var.* Kitchen Blend) Basils under different LED light quality

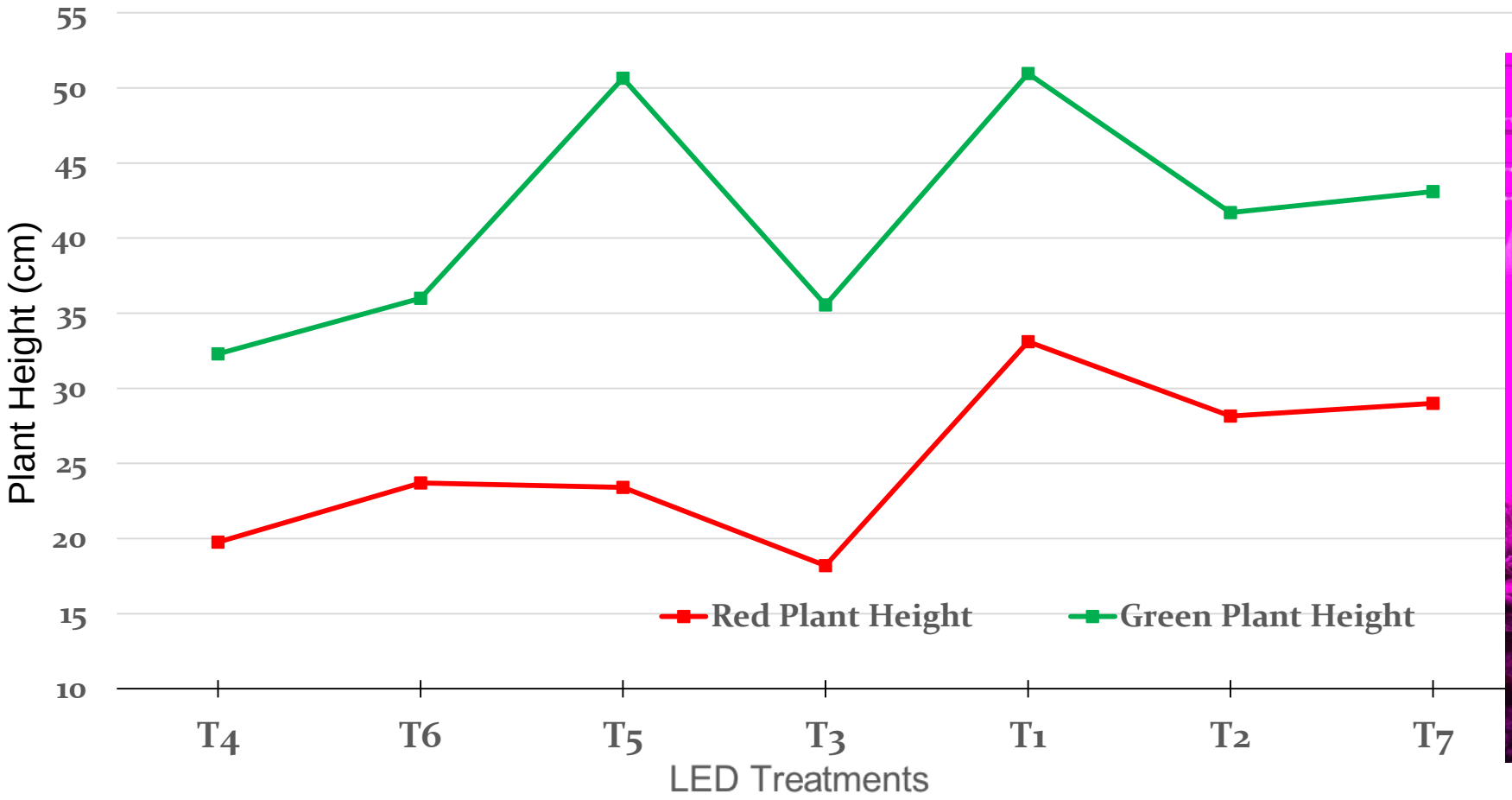


Effect of different light qualities on leaf number of green vs. red basil's

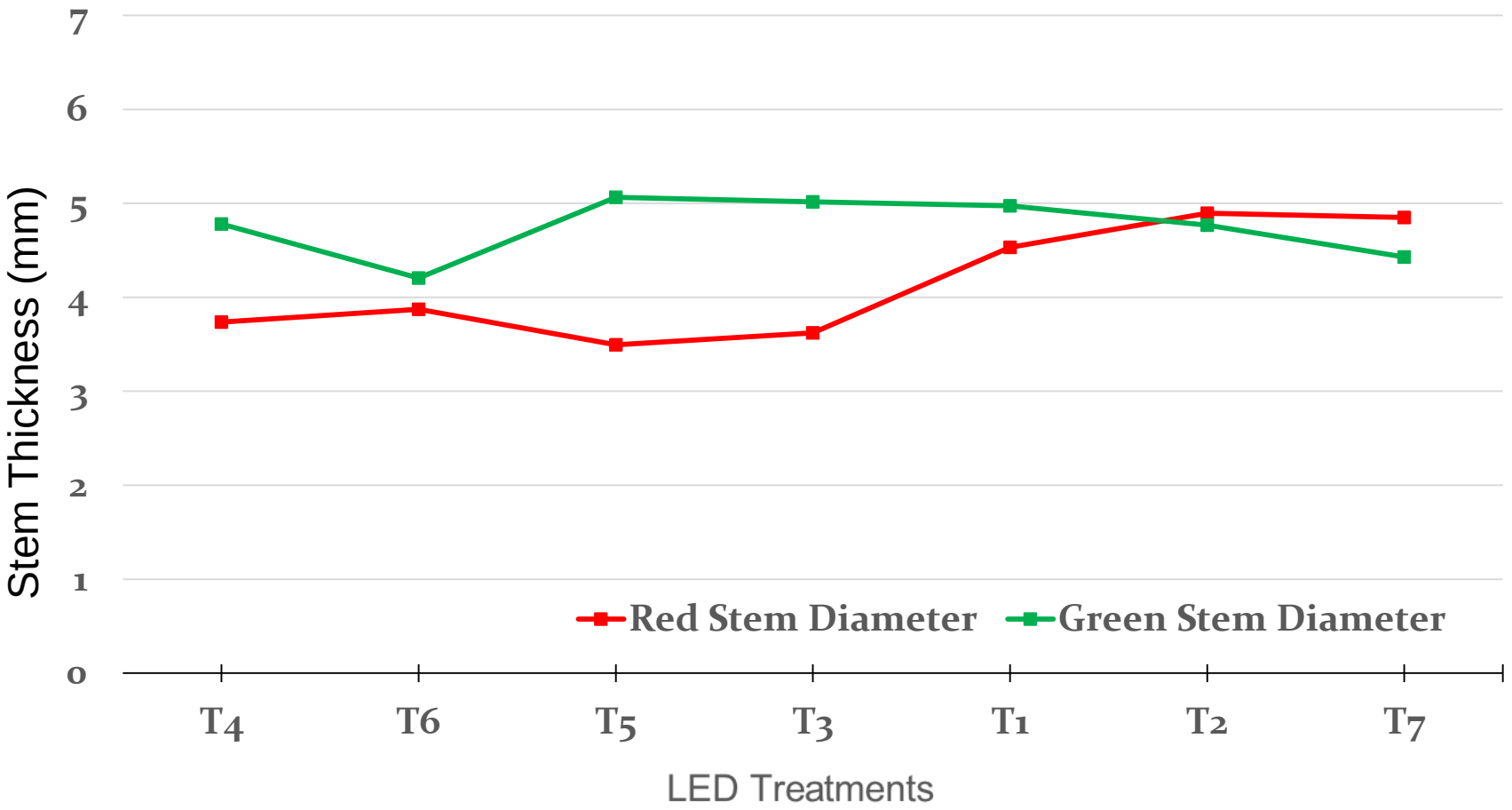




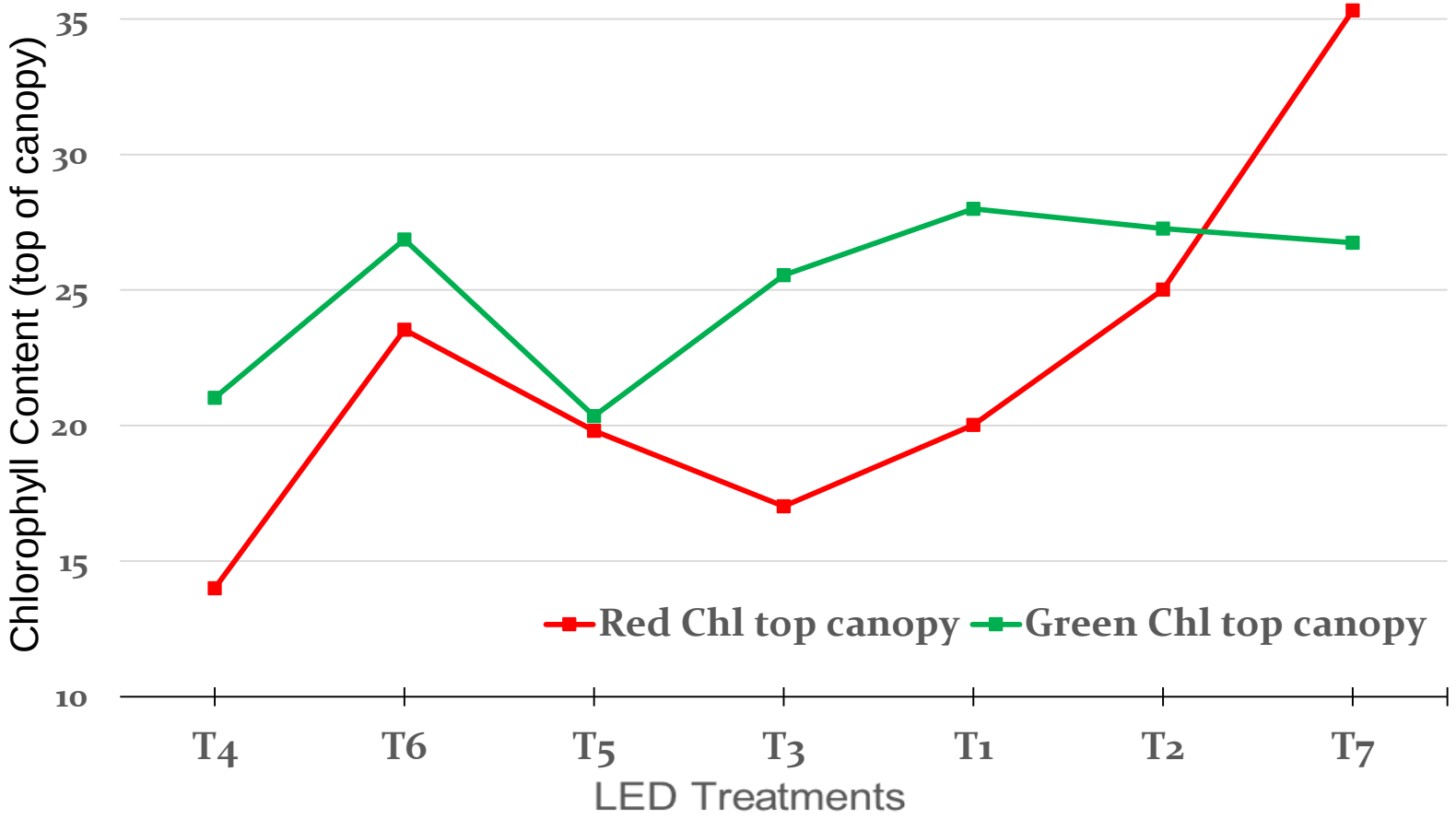
Effect of different light qualities on plant height of Green (*var.* Holy Basil) vs. Red (*var.* Kitchen Blend) Basil's

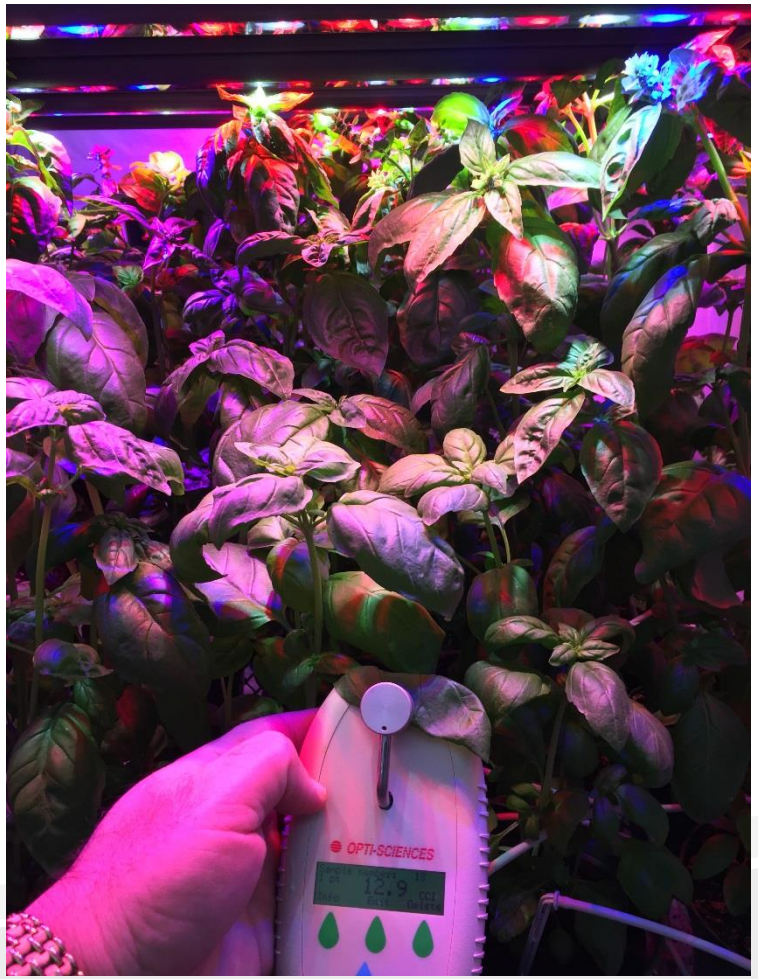


Effect of different light qualities on stem thickness of Green (*var.* Holy Basil) vs. Red (*var.* Kitchen Blend) Basil's

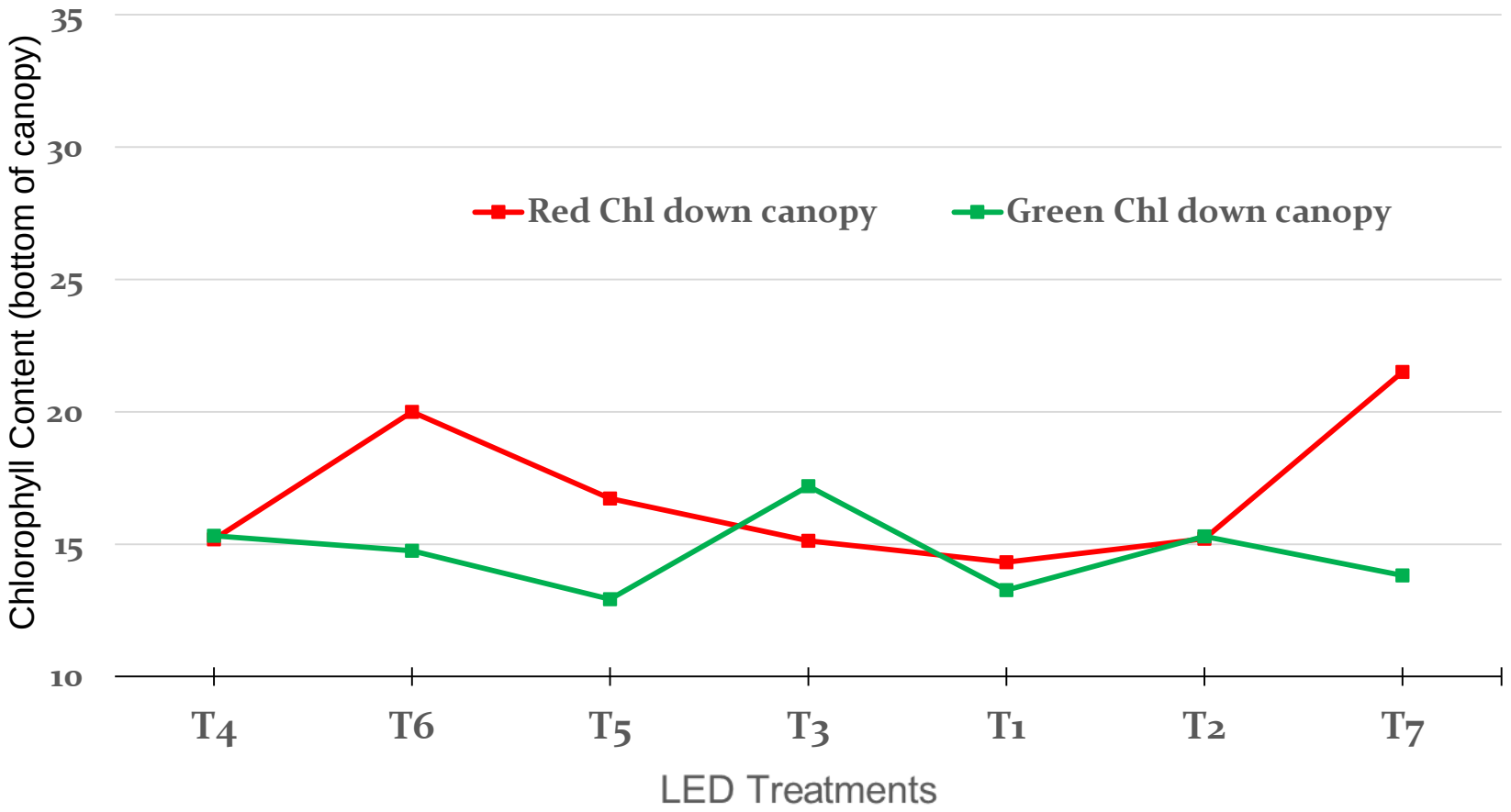


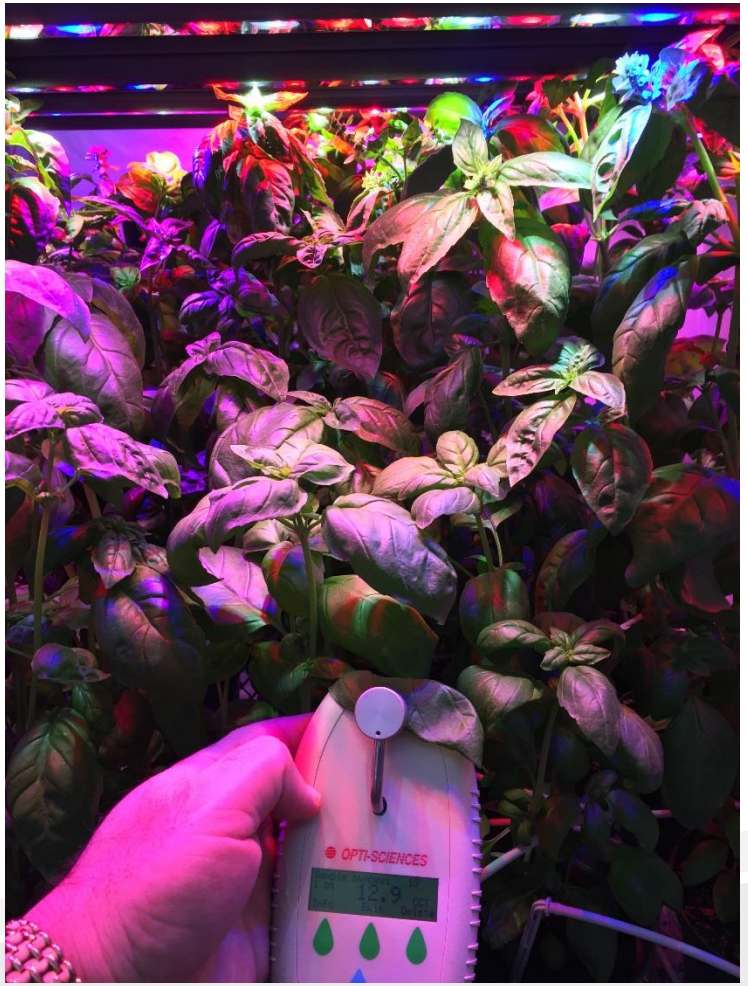
Effect of different light qualities on Chlorophyll content (**top** of canopy) of Green vs. Red Basil's



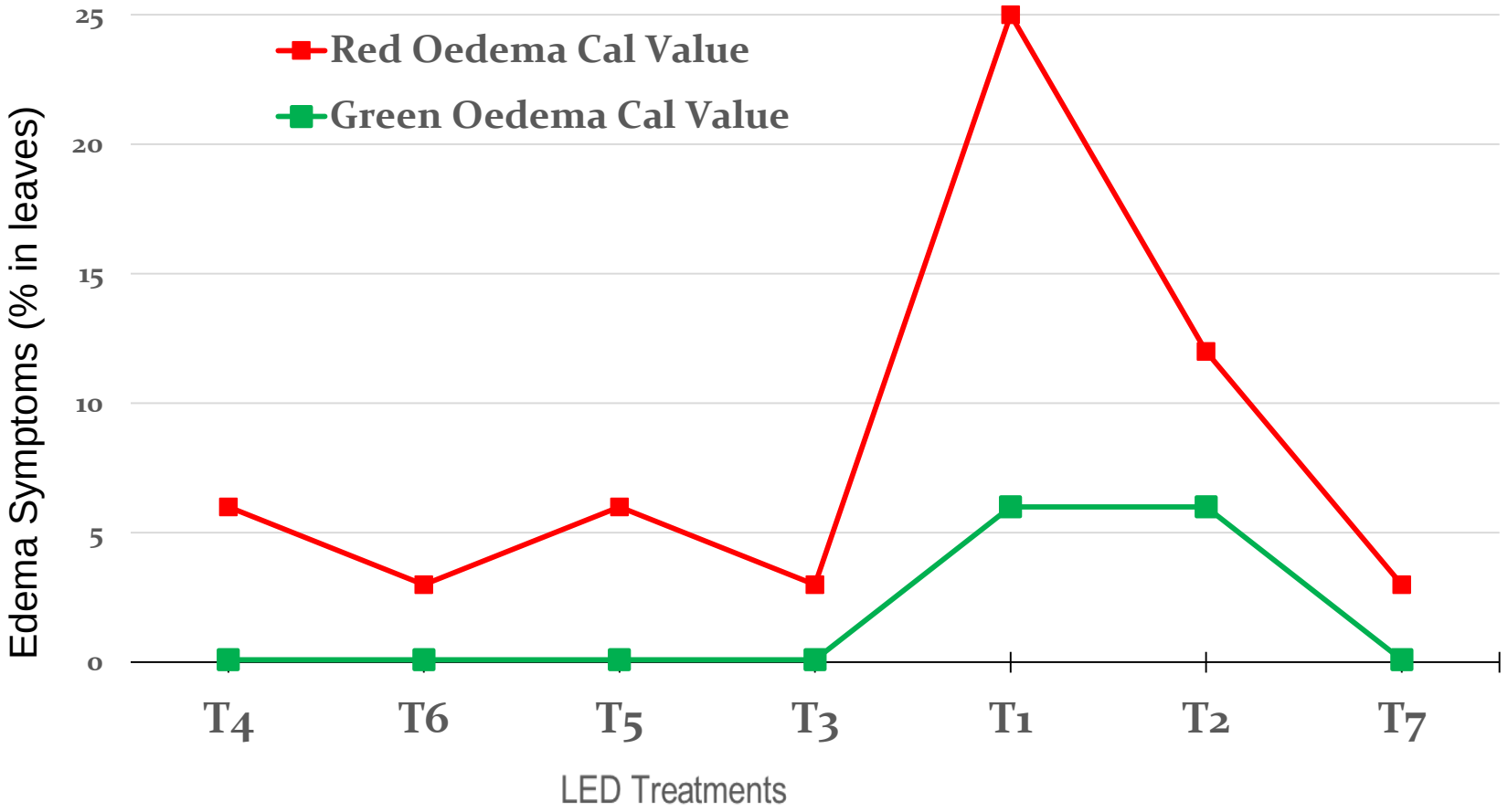


Effect of different light qualities on Chlorophyll content (**bottom** of canopy) Green vs. Red Basil's





Effect of different light qualities on edematous symptoms
Green (*var.* Holy Basil) vs. Red (*var.* Kitchen Blend) Basil's



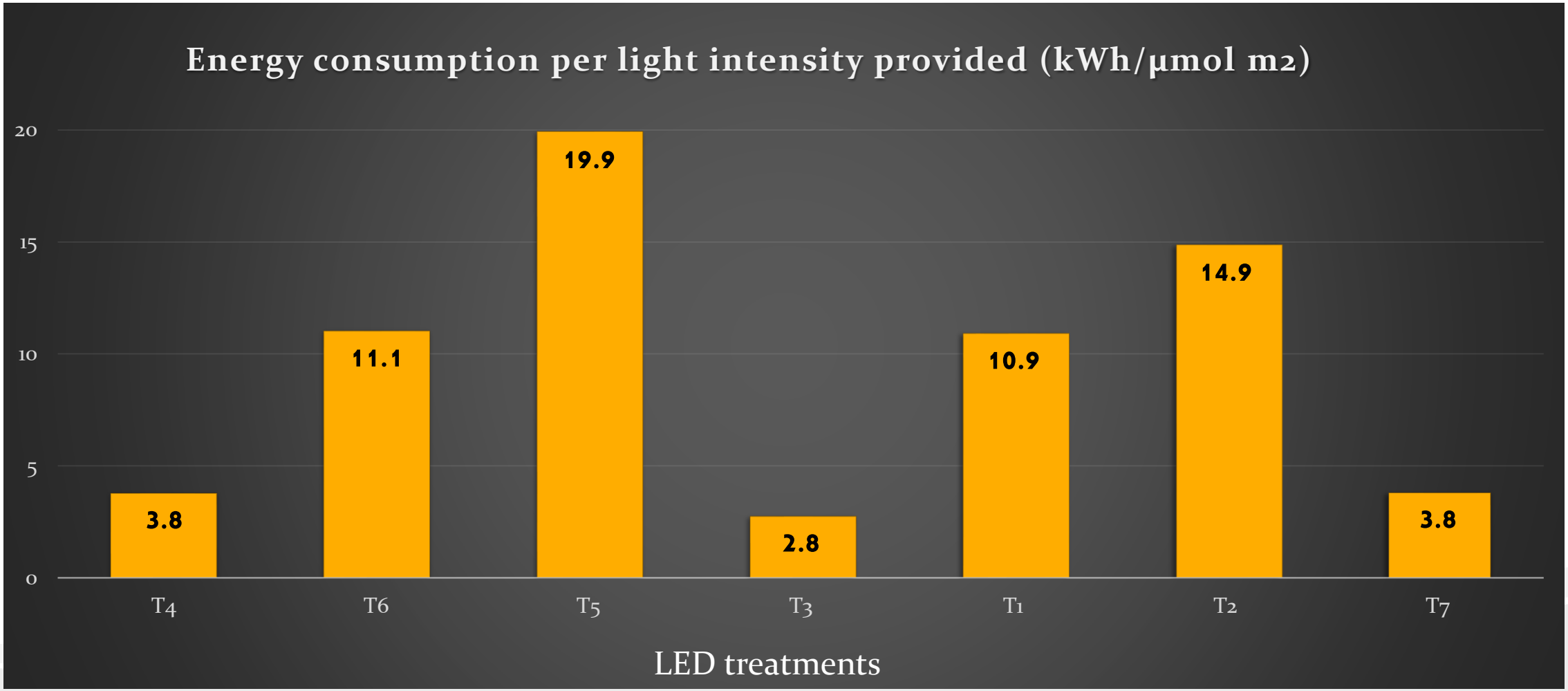
Existing Light Spectrum in Tested LEDs

- Better penetration in leaf tissue
- Stomata regulation
- Provide shorter internodes
- Thicker and darker leaves
- Increased root mass
- Flower induction
- Increased anthocyanin concentration

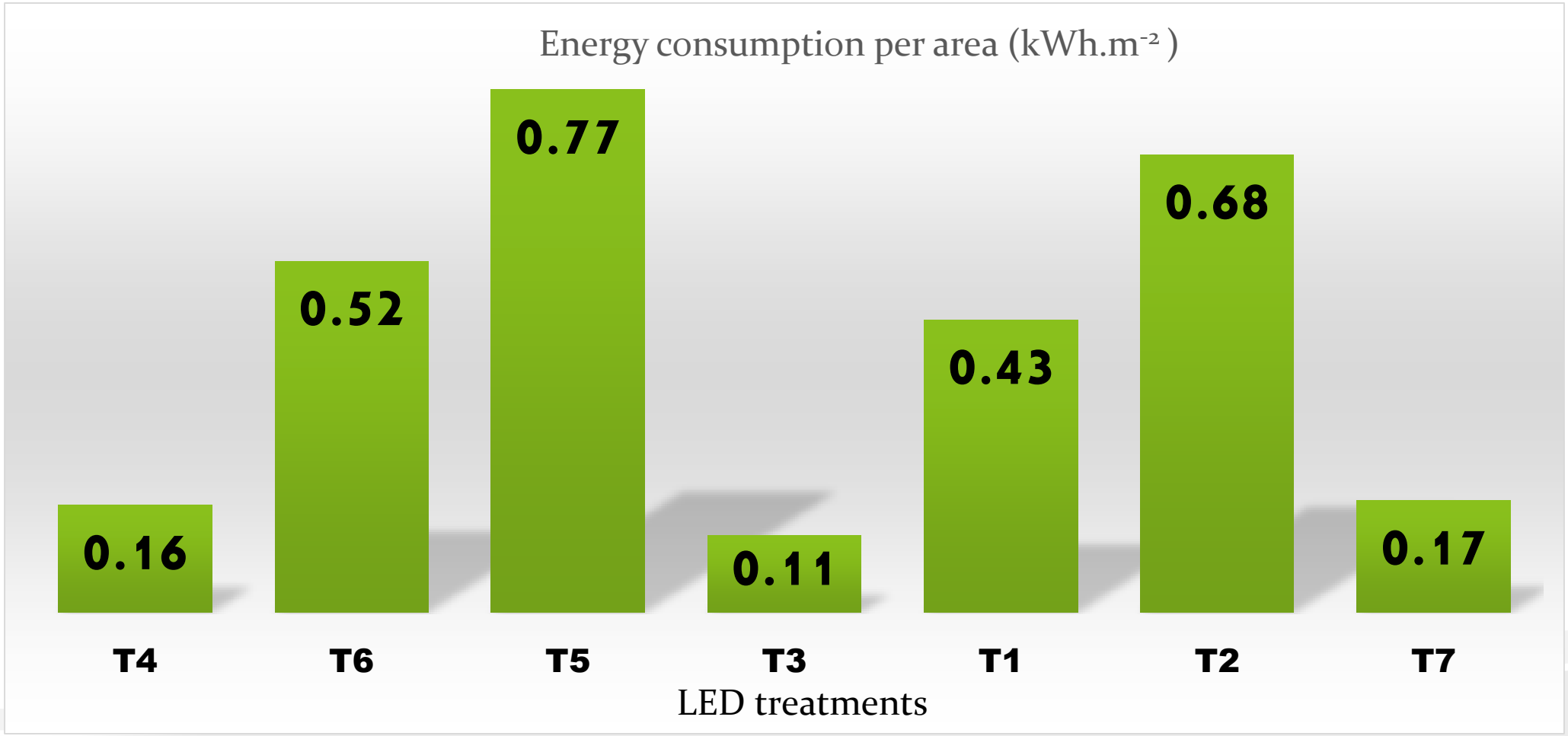
- More efficient at driving photosynthesis
- LEDs are less efficient in converting energy than Blue LEDs
- Stimulate root formation
- Enhanced flowering in long day plants
- Increased branching in long day plants

- Flower induction (Red:Far-red ratio)
- Branching
- Internode length
- Leaf thickness
- Chlorophyll content

If we classify all seven LEDs into two low and high energy efficiency classes, we have T3, T4, and T7 vs. T1, T2, T5, and T6 LEDs have used **3.5** and **14.2** (kWh/µmol m^2) electricity, respectively.



We have higher energy efficiency using T4, T3, and T7 *vs.* T1, T2, T5, and T6 by fourfold



For better evaluation of tested LEDs:

- Rank based on crop productivity
- Rank based on energy efficiency
- Rank based on light quality

LED types	Crop productivity (yield, kg/m2)	Energy efficiency (kW/µmol.m²)	Light quality
T1	2.64	10.9	Blue + Green+ Red + Far red(high)
T2	3.85	14.9	Blue + Red
T3	2.15	2.8	Whole PAR spectrum
T4	1.37	3.8	Whole PAR spectrum
T5	2	19.9	Blue + Red + Far red (low)
T6	1.92	11.1	Blue + Red + Far red (low)
T7	3.99	3.8	Blue + Red

Edema symptom and subsequent leaf necrosis

- Leaf necrosis was reported in both our preliminary trial and current **tomato** lighting project under LED (up to 43%) and HPS (up to 20%), when sunlight is minimum!!!!
- What is the cause of edema under supplementary lighting?
- How can we eliminate / reduce edema?

ACKNOWLEDGMENT:

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My colleagues:

- John Zhang
- Marlon Anoso
- Tommy Li

ACIDF
Alberta Crop Industry Development Fund Ltd.

Growing Forward 2
A federal-provincial-territorial initiative