NCERA-101: Committee on Controlled Environment Technology and Use
2021 Station Report

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Mark Lefsrud and Bo-Sen Wu, November 7, 2021

1. **New Facilities and Equipment**.
   Nothing to report.

2. **Unique Plant Responses.**
   Chlorophyll's light-harvesting role in photosynthesis has not been challenged in over 40 years. Using light emitting diodes and a high-resolution monochromator, we developed a method to measure at 1-nm increments a spectral photosynthesis curve determined in tomato plants with a 10-nm bandwidth light spectrum. Minimal photosynthetic rates (μmol CO_2 m^{-2} s^{-1} nm^{-1}) were recorded at spectra corresponding to peak chlorophyll absorbance (420 nm and 660 nm for chlorophyll *a*, and 450 and 640 nm for chlorophyll *b*), showing that extracted pigment absorbance peaks and photosynthesis are inversely correlated. Photosynthesis theory decrees that photosynthetic pigments drive photosynthesis, and that these pigments absorb and convert specific wavelengths of light energy into chemical energy. Our finding implies that chlorophyll may carry out an additional regulatory function in photosynthesis that has not yet been identified.

3. **Accomplishment Summaries.**
   The Biomass Production Laboratory at Macdonald Campus of McGill University is investigating the relationship between pigment absorbance and supplemental lighting for crop production. We have shown that the maximum photosynthetic activity in tomato plants does not correlate with extracted pigment absorbance peaks. It is widely accepted that major pigments play an important role in harvesting light energy at specific wavelengths, according to their spectral absorbance (blue and red light. This knowledge has led to the widespread application of blue/red LEDs for plant growth. Yet, with decades of research, the optimal light ratio of these two wavelengths remains elusive. More importantly, this purplish light should theoretically outperform any other lighting system in the market, but purplish lighting configurations do not increase plant growth rates or result in better plant yields when compared to conventional lighting systems in controlled environment agriculture (i.e. amber-light-abundant high-pressure sodium lamps. Nearly five decades ago, photobiologists reported optimal lighting configurations based on spectral photosynthesis curves. Although comparisons between spectral peaks of photosynthetic activity and extracted pigment absorbance were not attempted at the time, reported spectral photosynthesis peaks do not correlate with extracted pigment absorbance peaks.

Figure

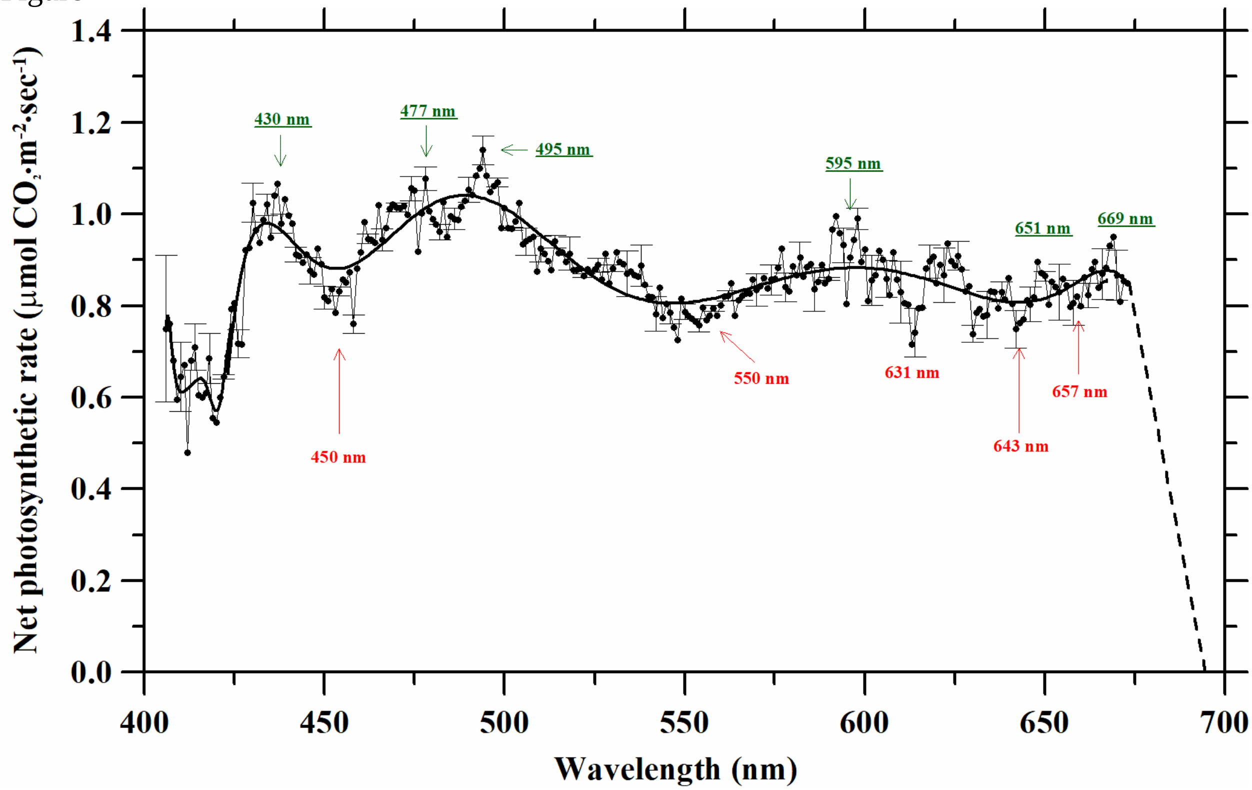

Figure 1. The 1-nm increment spectral photosynthesis curves plotted with high resolution data acquired from the spectral responses of young tomato (*S. lycopersicum*) (405 nm to 670 nm). Error bars through data points represent standard error. Wavelengths indicated in green and in red refer to peaks and valleys, respectively.

4. Impact Statements.

The Biomass Production Laboratory at McGill University has an alternative theory of photosynthesis. Our present interpretation of photosynthesis is such that major light-capturing pigments drive photosynthesis by funneling and transferring specific wavelengths of light energy, ultimately converting this energy into chemical energy for photosynthesis. These pigments are the main components of photosystems I and II, in addition to the antenna complex. The importance and essential functions of these photosynthetic pigments have not been questioned since their absorbance properties were first characterized. Likewise, the basic theory of photosynthesis is based on the absorbance characteristics of these pigments. Our laboratory findings do not conform to these existing theories. The spectral photosynthesis curve reported in our laboratory shows that an alternate function for photosynthetic pigments may exist, rather than solely absorbing and utilizing the light at specific wavelengths based on their absorbance spectra. With this, we suggest that a new theory is required to better understand the role that pigments play in photosynthesis.

5. Published Written Works.

- Addo, P.W., V. Desaulniers Brousseau, V. Morello, S. MacPherson, M. Paris, M. Lefsrud. 2021. Cannabis chemistry, post-harvest processing methods and secondary metabolite profiling: A review. Industrial Crops & Products 170:113743

- Desaulniers Brousseau, V., B.-S Wu, S. MacPherson, V. Morello, M. Lefsrud. 2021. Cannabinoids and terpenes: how production of photo-protectants can be manipulated to enhance Cannabis sativa L. phytochemistry. Frontiers in Plant Science-Plant Metabolism and Chemodiversity 31: doi.org/10.3389/fpls.2021.620021
- Hitti, Y., J. Chapelat, B.S. Wu, M. Lefsrud. 2021. Design and Testing of Bioreceptive Porous Concrete: A New Substrate for Soilless Plant Growth. ACS Agric Sci Technol. doi.org/10.1021/acsagscitech.0c00065
- Parrine, D., T. Greco, B. Muhammad, B.-S. Wu, X. Zhao, M. Lefsrud. 2021. Color-specific response to extreme high-light stress in plants. Life 11:812
- Seguin, R. M.G. Lefsrud, T. Delormier, J. Adamowski. 2021. Assessing constraints to agricultural development in circumpolar Canada through an innovation systems lens. Agricultural Systems 194:103268
- Warner, R., B.S. Wu, S. MacPherson, M. Lefsrud. 2021. A review of strawberry photobiology research and its flavonoid profile in controlled environment. Frontiers in Plant Science 12:611893.
- Wu, B.S. S. MacPherson, M. G. Lefsrud. 2021. Filtering light-emitting diode spectra to investigate narrow wavelength effects on lettuce growth. Plants 10(6):1075 (IP: 3.935)
- Wu, B.-S., Y. Hitti, S. MacPherson, V. Orsat, M. G. Lefsrud. 2020. Comparison and perspective of conventional and LED lighting for photobiological and industry applications. Environmental and Experimental Botany 171:103953.
- Yavari, N., R. Tripathi, B.S. Wu, S. MacPherson, J. Singh, M. Lefsrud. 2021 The effect of light qualities on plant physiology, photosynthetic, and stress response in Arabidopsis thaliana leaves. PLoS ONE 16(3): e0247380

6. **Other relevant accomplishments and activities**.

Benjamin Goldstein, and Shangpeng Sun have been hired as assistant professors in the Department of Bioresource Engineering at McGill University. Dr Goldstein is interested in understanding how the consumption of materials and energy in cities produce environmental change inside and outside cities. Dr. Sun’s main research interests are to develop and adopt innovative sensing technologies and computational methodology for solving challenges in next-generation smart agriculture, aiming to improve the production of high-quality food in the face of the rapidly growing human population and global environmental change.