2023 NCERA-101 Station Report – Cornell University

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1. New Facilities and Equipment.

- Cornell University has equipped two greenhouse sections with dimmable white LEDs (TSRGrow). Cornell implemented a lighting algorithm that interfaces with the Argus Climate control system to adjust light output every 10 minutes to complement the sun to set instantaneous lighting target.

2. Unique Plant Responses.

- In a greenhouse lettuce study at Cornell University during winter, growth of lettuce 'Rex' and 'Rouxai' was compared under HPS, MH, red:blue LEDs, and white LEDs. The same daily light integral was applied across treatment and the experiment was repeated three times. HPS fixtures led to greater fresh weight than red:blue LEDs. While HPS plants consumed more water per plant, on a water used per unit of fresh mass basis the HPS plants used less water than red:blue LEDs. The nutritional composition (anthocyanins and xanthophylls) were greatest under red:blue LEDs as compared to white LEDs or HPS. More work is needed to balance high plant productivity with nutrition, suggesting promise in dynamically changing light spectrum during the crop cycle.

3. Accomplishments:

3.A. Short-term Outcomes:

- Far-red radiation (700-750 nm) is often ignored by lighting manufacturers as the traditional definition of photosynthetically active radiation includes 400-700 nm light. Several NCERA-101 members have worked to understand the role of far-red in commercial CEA production. In experiments at Cornell University with lettuce 'Rex' under sole-source lighting we found plants that received 20% far-red (vs. 2% far-red control) had a 70-80% larger fresh and dry weight.

3.B. Outputs:

- In February/March 2023, the Greenhouse Lighting and Systems Engineering (GLASE) consortium which is led by Cornell University, Rutgers University, and Rensselaer Polytechnic Institute and with 30 industry members held a virtual climate control short course spanning six weeks. The course drew 239 participants.

3.C. Activities:

- Winter producers of petunias as bedding plants have difficulties getting some cultivars to flower on time and have sufficient branching and size to fill their containers. At Cornell University greenhouse experiments, the impact of daily

light integral (DLI, at 6, 9, 12, or 15 mol m^{-2} d^{-1}) combined with 0 or 30 µmol m^{-2} s^{-1} far-red during the liner production stage was evaluated on subsequent size and flowering. Little impact of far-red was observed except at 6 mol m^{-2} d^{-1} where far-red caused early flowering but also resulted in excessive plant stretch). Increasing DLI to 12 or 15 mol m^{-2} d^{-1} substantially improved plant quality (branching, flower number, and days to flower).

3.D. Milestones:

- Cornell University is planning 8 commercial greenhouse pilot projects to test advanced greenhouse lighting control systems in 2023 as part of a NY Specialty Crop Block Grant. Energy savings vs. baseline controls will be quantified.
- Cornell University and collaborators at Rutgers University and Rensselaer Polytechnic Institute are planning the next Greenhouse Lighting and Systems Engineering Summit to provide technical information to CEA industry members for October 25, 2023 in Leamington, Ontario.

4. **Impact Statements**.

- Over 80 percent of surveyed participants of the GLASE climate control short course plan to implement new practices in their operation as a result of the course including: light respacing, installing controllers for dehumidification, evaluation sensor location and calibration, integrating new sensors and controls and implementing energy saving tips.

5. **Published Written Works**

Refereed Journal Articles

Ashenafi, E.L., Nyman, M.C., Holley, J.M. and Mattson, N.S., 2023. The influence of LEDs with different blue peak emission wavelengths on the biomass, morphology, and nutrient content of kale cultivars. Scientia Horticulturae, 317, p.111992.

Eaton, M., Shelford, T., Cole, M. and Mattson, N., 2023. Modeling resource consumption and carbon emissions associated with lettuce production in plant factories. Journal of Cleaner Production, 384, p.135569.

Ajagekar, A., Mattson, N.S. and You, F., 2023. Energy-efficient AI-based Control of Semi-closed Greenhouses Leveraging Robust Optimization in Deep Reinforcement Learning. Advances in Applied Energy, 9, p.100119.

Ashenafi, E.L., Nyman, M.C., Shelley, J.T. and Mattson, N.S., 2023. Spectral properties and stability of selected carotenoid and chlorophyll compounds in different solvent systems. Food Chemistry Advances, 2, p.100178.

Xia, J., Mattson, N., Stelick, A. and Dando, R., 2022. Sensory Evaluation of Common Ice Plant (Mesembryanthemum crystallinum L.) in Response to Sodium Chloride Concentration in Hydroponic Nutrient Solution. Foods, 11(18), p.2790.

Holley, J., Mattson, N., Ashenafi, E. and Nyman, M., 2022. The Impact of CO2 Enrichment on Biomass, Carotenoids, Xanthophyll, and Mineral Content of Lettuce (Lactuca sativa L.). Horticulturae, 8(9), p.820.

Xia, J. and Mattson, N., 2022. Response of common ice plant (Mesembryanthemum crystallinum L.) to photoperiod/daily light integral in vertical hydroponic production. Horticulturae, 8(7), p.653.

Xia, J. and Mattson, N., 2022. Response of common ice plant (Mesembryanthemum crystallinum L.) to sodium chloride concentration in hydroponic nutrient solution. HortScience, 57(7), pp.750-756.

Chen, W.H., Mattson, N.S. and You, F., 2022. Intelligent control and energy optimization in controlled environment agriculture via nonlinear model predictive control of semi-closed greenhouse. Applied Energy, 320, p.119334.

Ashenafi, E.L., Nyman, M.C., Holley, J.M., Mattson, N.S. and Rangarajan, A., 2022. Phenotypic plasticity and nutritional quality of three kale cultivars (Brassica oleracea L. var. acephala) under field, greenhouse, and growth chamber environments. Environmental and Experimental Botany, p.104895.

Yamori, N., Levine, C.P., Mattson, N.S. and Yamori, W., 2022. Optimum root zone temperature of photosynthesis and plant growth depends on air temperature in lettuce plants. Plant Molecular Biology, pp.1-11.

Rodgers, D., Won, E., Timmons, M.B. and Mattson, N., 2022. Complementary nutrients in decoupled aquaponics enhance basil performance. Horticulturae, 8(2), p.111.

Symposium Proceedings

Mattson, N.S., Allred, J.A., de Villiers, D., Shelford, T.J. and K. Harbick 2022. Response of hydroponic baby leaf greens to LED and HPS supplemental lighting. ISHS LightSym2021. 9th International Symposium on Light in Horticultural Systems. Acta Horticulturae. 1337:395-402.

Harbick, K. and Mattson, N.S. 2022. Optimization of spatial lighting uniformity using non-planar arrays and intensity modulation. ISHS LightSym2021. 9th International Symposium on Light in Horticultural Systems. Acta Horticulturae. 1337: 101-106.

Shelford, T., Both, A.J. and Mattson, N.S. 2022. A greenhouse daily light integral control algorithm that takes advantage of day ahead market electricity pricing. ISHS LightSym2021. 9th International Symposium on Light in Horticultural Systems. Acta Horticulturae. 1337:277-282.