Michigan State University 2021-22 Station Report
NCERA-101: Committee on Controlled Environment Technology & Use

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Accomplishment summaries

- We coordinated several outreach programs that delivered unbiased, research-based information on producing plants in controlled environments, including the Michigan Greenhouse Growers Expo and the Floriculture Research Alliance annual meeting.
- In collaboration with colleagues at Arizona, Michigan State, Purdue, Ohio State, and the USDA-ARS, we completed the second year of our research and outreach project entitled "Improving the profitability and sustainability of indoor leafy-greens production".
- Ph.D. student Hyeonjeong Kang and Roberto Lopez investigated the influence of the photosynthetic daily light integral and root-zone temperature on rooting of tropical foliage plants during propagation. A daily light integral between 6 to 10 $mol \cdot m^{-2} \cdot d^{-1}$ is recommended because further increases have minimal impact on root growth or quality. The greatest root dry mass was recorded when cuttings were rooted at a root-zone temperature of 25 °C.
- Ph.D. student Nathan Kelly and Erik Runkle studied the effects of dynamic UV-A or blue light on red-leaf lettuce growth and quality attributes. We grew lettuce under white plus red LEDs and delivered additional UV-A or blue light during one of three eight-day phases, or continuously. UV-A or blue light applied during the final phase of production or continuously equally increased secondary metabolite concentrations and leaf coloration, but growth was inhibited under continuous supplemental blue light.
- Nathan Kelly and Erik Runkle studied lettuce grown indoors to determine how background lighting (various combinations of blue, green, and red light) influences the effectiveness of far-red light at increasing biomass accumulation. Preliminary results indicate lettuce biomass was the lowest when either no far-red light was present or when far-red light was delivered at its maximum intensity, as long as green light was included in the photon spectrum.
- Ph.D. student Eric Stallknecht and Erik Runkle investigated the mechanism by which an experimental red-fluorescent greenhouse cover increases the biomass accumulation of floriculture, leafy green, and fruiting crops. In part, red-fluorescent materials increased biomass accumulation by increasing leaf area, which was correlated with a decrease in the transmission of blue light. However, the blue light fraction did not completely explain plant growth responses, suggesting effects of the green- and red-light fractions.
- Eric Stallknecht and Erik Runkle investigated how experimental photovoltaic greenhouse glazing materials influenced the morphology and yield of greenhouse crops. Preliminary results indicate some crops can tolerate minimal to moderate shading caused by photovoltaic panels without decreasing yield, whereas other crops could not. These findings reiterate the necessity of carefully designing combined agricultural and photovoltaic systems considering the crop type, photovoltaic panel type, location, and time of year.

- Ph.D. student Jiyong Shin and Erik Runkle studied the interaction between air temperature and photon spectra on the growth of lettuce and basil grown indoors. Preliminary research indicates that air temperature and photon spectra interacted in determining the growth and morphology of the leafy green species. This suggests that air temperature and photon spectra need to be simultaneously considered when developing indoor plant production protocols.
- Research technician Annika Kohler and Erik Runkle examined the influence of light intensity and spectrum on the morphology and shelf stability of frill-leaf lettuce grown indoors. Under a relatively high ratio of blue to red light, both lettuce cultivars were compact, had less fresh mass, and greater chlorophyll content than plants grown under a lower light ratio. After 9 days of refrigeration, one cultivar grown under high light with the highest ratio of blue to red light decayed quicker than the other lighting treatments.
- Former M.S. student Sean Tarr and Roberto Lopez performed experiments and established the base and optimum temperatures for fresh accumulation of arugula, kale, red oakleaf lettuce, and green butterhead lettuce.
- Sean Tarr and Roberto Lopez modeled how the photosynthetic photon flux density and CO_2 concentration interact with mean daily temperature to influence the growth, yield, and quality of hydroponically grown green butterhead and red oakleaf lettuce. Dry mass of both cultivars was influenced by the interaction of CO_2 and temperature; biomass accumulation was greatest at 800 $\mu mol \cdot mol^{-1}$ CO_2 at temperatures of 73 or 79 °F (23 or 26 °C).
- Sean Tarr and Roberto Lopez investigated how the day length provided to marigold 'Xochi' young plants influenced subsequent flowering and cut flower quality. Regardless of the photoperiod provided, time to visible bud and open flower were similar across the young-plant photoperiods tested. Stem length at harvest was greatest when seedlings were grown under photoperiods of 13 to 16 hours.
- M.S. student Devin Brewer and Roberto Lopez quantified the influence of blue or blue + red end-of-production (EOP) sole-source lighting on red-leaf lettuce. Results indicate that light intensity was more effective at increasing anthocyanin content than light quality alone. However, 100% blue light at the end of production increased mineral nutrient content beyond levels quantified in plants not receiving additional lighting.
- M.S. student Caleb Spall and Roberto Lopez investigated the influence of supplemental light quality on time to harvest and finished quality of several specialty cut flowers. Time to harvest of cut flowers with a long-day flowering response was hastened when grown under blue, red, and far-red light combined, or 100% blue light, compared to cut flowers grown under 100% red light. Stem lengths were greatest under 100% red light.

Impact statements

- The Michigan Greenhouse Growers Expo, Electronic Grower Resources Online, and The Floriculture Research Alliance meetings delivered unbiased, research-based information to over 3,000 greenhouse growers, plus additional growers and marketers of vegetable and fruit crops.
- Unlike annual bedding plants, daily light integral has minimal impact on root dry mass of foliage crops during propagation. Root-zone and air temperature have a greater impact on root and shoot growth during propagation and production.

- We learned that end-of-production UV-A or blue light can be equally effective at increasing the concentrations of some secondary metabolites, as well as leaf coloration, as continuous lighting. However, supplemental blue light inhibited biomass accumulation of lettuce, while end-of-production blue light did not.
- We generated models that predict the base, optimum, and maximum temperatures of leafy greens that will help growers determine production temperature setpoints and conduct cost-benefit analyses.
- We learned that moderate intensity end-of-production lighting may significantly affect phytochemical, nutrient, and morphological features of leafy greens.
- Red-fluorescent shading materials can increase the biomass accumulation of floriculture, leafy green, and fruiting crops compared to materials that do not change the light spectrum. Commercial implementation will depend in part on the product cost and longevity, crops grown, greenhouse location, and time of year.
- The implementation of photovoltaics into agricultural systems requires the proper validation of crop type, geographical location, and photovoltaic cover type. Trade-offs that exist between energy generation and plant growth will need to be evaluated for each growing situation.

Published written works (since 2020-21 report)

Theses

Caleb Spall (M.S. student) Manipulating photon flux density, photon spectrum, and photoperiod to improve the greenhouse production of specialty cut flowers. Graduation, July 2022.

Sean Tarr (M.S. student) Improving yield and quality of leafy greens grown indoors with precise radiation, temperature, and carbon dioxide. Graduation, May 2022.

Book chapters

Blanchard, M. and E. Runkle. 2021. Temperature, p. 64-79. In: J. Nau et al. (eds.). Ball Redbook, 19th ed., vol. 2. Ball Publishing, Chicago, IL.

Currey, C. and R.G. Lopez. 2021. Managing photoperiod in the greenhouse. p. 47−49. In: C. Beytes (ed.). Ball Redbook, 19th ed., vol. 1. Ball Publishing, Chicago, IL.

Kelly, N., V. Vaštakaitė-Kairienė, and E.S. Runkle. 2022. Indoor lighting effects on plant nutritional compounds, p. 329-349. In: Kozai et al. (eds.). Plant Factory Basics, Applications, and Advances. Academic Press, London.

Lopez, R.G. and C. Currey. 2021. Light management. Crop culture and production. p. 80−89. In: J. Nau et al. (eds.). Ball Redbook, 19th ed., vol. 2. Ball Publishing, Chicago, IL.

Park, Y., C. Gomez, and E.S. Runkle. 2022. Indoor production of ornamental seedlings, vegetable transplants, and microgreens, p. 351-375. In: Kozai et al. (eds.). Plant Factory Basics, Applications, and Advances. Academic Press, London.

Runkle, E. 2021. Supplemental greenhouse lighting, p. 123-128. In: C. Beytes (ed.). Ball Redbook, 19th ed., vol. 1. Ball Publishing, West Chicago, IL.

Twaddell, J. and R. Lopez. 2021. Propagating vegetative crops p. 154−169. In: J. Nau et al. (eds.). Ball Redbook, 19th ed., vol. 2. Ball Publishing, Chicago, IL.

Scientific manuscripts

Kohler, A. and R.G. Lopez. 2022. Air temperature during cutting propagation of cold-intermediate and –sensitive crops can be reduced if root-zone heating is provided. Sci. Hort. 304:1–8.

Kohler, A., DuRussel, N. and R.G. Lopez. 2022. A foliar spray application of indole-3-butyric acid promotes rooting of herbaceous annual cuttings similarly or better than a basal dip. Sci. Hort. 305:1–11.

Runkle, E.S., Y. Park, and Q. Meng. 2022. High photosynthetic photon flux density can attenuate effects of light quality. Acta Hort. 1337:333-340.

Vaštakaitė-Kairienė, V., A. Brazaitytė, J. Miliauskienė, R. Sutulienė, K. Laužikė, A. Viršilė, G. Samuolienė, and E.S. Runkle. 2022. Photon distribution of sole-source lighting affects the mineral nutrient content of microgreens. Agriculture 12:1086.

Walters, K.J. and R.G. Lopez. 2022. Hydroponic basil production: Temperature influences volatile organic compound profile, but not overall consumer preference. Horticulturae 8(1):76.

Whitman, C., S. Padhye, and E.S. Runkle. 2022. A high daily light integral can influence photoperiodic flowering responses in long day herbaceous ornamentals. Sci. Hort. 295:110897.

Trade articles

Kacira. M., P.-E. Bournet, L.R. Khot, Q. Yang, I.L. Cruz, W. Luo, H.J. Schenk, H. Fatnassi and R. Lopez. 2021. Sustaining the future with precision horticulture and engineering. Chronica Horticulturae 61(2):17−20.

Kelly, N., Q. Meng, and E. Runkle. Photoperiod, light intensity, and daily light integral. Produce Grower Mar.:16-19.

Kohler A. and R.G. Lopez. 2022. A study of the latest young plant technology: Getting to the root of basewell cuttings. GrowerTalks 85(11):48–49.

Kohler, A., A. Soster, and R.G. Lopez. 2022. PGRs and succulents. Greenhouse Product News 32(7):26–31.

Lopez. R., C. Kubota, E. Runkle and C. Mitchell. 2022. Indoor farming FAQs. Inside Grower 10(2):48–49.

Lopez. R. 2022. Are there risks of working under LED supplemental lighting? E-GRO Alert 11(10):1–5.

Meng, Q. and E. Runkle. 2022. Fixed vs. dynamic light quality for indoor hydroponic lettuce. Produce Grower Feb.:14-17.

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Runkle, E. 2022. Air, leaf, and root-zone temperature. Greenhouse Product News 32(7):50.

Runkle, E. 2022. Blue light as a PGR. Greenhouse Product News 32(2):50.

Runkle, E. 2022. Evaporative cooling, part 1: Methods. Greenhouse Product News 32(4):42.

Runkle, E. 2022. Evaporative cooling, part 2: Maintenance. Greenhouse Product News 32(6):42.

Runkle, E. 2022. Futuristic light(ing) in horticulture. Greenhouse Product News 32(8):42.

Runkle, E. 2022. Light and temperature responses of bedding plants. Greenhouse Product News 32(3):34.

Runkle, E. 2021. The buzz of secondary metabolites. Greenhouse Product News 31(11):42.

Runkle, E. 2022. The shade-avoidance response. Greenhouse Product News 32(5):58.

Runkle, E. 2021. Water vapor-pressure deficit. Greenhouse Product News 31(12):34.

Runkle, E., M. Kacira, and C. Mitchell. 2022. More questions answered. Inside Grower Aug.:16-17.
Spall, C. and R.G. Lopez. 2022. Blooming by lamplight. Greenhouse Product News 32(6):28–31.
Walters, K.J. and R.G. Lopez. 2021. Culinary herbs: Balancing light and average daily temperature. Produce Grower. 18–21.
Walters, K. and R.G. Lopez. 2021. Lighting up basil flavor. Produce Grower. 40–44.