Michigan State University 2020-21 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.
- We updated the MSU Extension Floriculture & Greenhouse Crop Production website that includes MSU-authored resources on the production of plants in controlled environments.
- Research technician Annika Kohler and Roberto Lopez quantified the effects of various rates of uniconazole on stem elongation under low (2.0 $mol \cdot m^{-2} \cdot d^{-1}$) and high (16.3 $mol \cdot m^{-2} \cdot d^{-1}$) daily light integrals of five succulent genera over time. Using at least 1 $mg \cdot L^{-1}$ of uniconazole was enough to suppress stem elongation in most succulents studied after 10 or 15 weeks but 2 $mg \cdot L^{-1}$ can be used for all succulents.
- M.S. student Caleb Spall and Roberto Lopez investigated the influence of supplemental light (SL) quality on time to harvest and finished quality of several long-day specialty cut flowers. Time to harvest under SL containing blue, red, and far-red radiation, or 100% blue radiation, was hastened compared to plants grown under high-pressure sodium or broad-spectrum LED SL. Additionally, time to harvest was delayed under 100% red SL.
- M.S. student Caleb Spall and Roberto Lopez investigated the influence of young- and finished-plant photoperiod on time to harvest and quality of several cut flowers. Marigold 'Xochi' seedlings grown under 11- to 24-h photoperiods or a 4-h night interruption and finished under 10- to 12-h days were marketable, and of comparable finished quality.
- M.S. student Sean Tarr and Roberto Lopez quantified the influence of day and night air temperatures (72/59, 77/64, 82/70 °F) and light intensities (150 to 300 $\mu mol \cdot m^{-2} \cdot s^{-1}$) on growth of red oakleaf and green butterhead lettuces 'Rouxaï' and 'Rex'. Fresh mass was greatest for both cultivars under 300 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of light and at day/night temperatures of 77/64 or 82/70 °F for 'Rouxaï' and 82/70 °f for 'Rex'. However, incidence of tip burn was greater under the higher light intensity.
- M.S. student Sean Tarr and Roberto Lopez investigated how air temperature and CO_2 concentration (500, 800, and 1200 $\mu mol \cdot mol^{-1}$) influenced growth of 'Rouxaï' and 'Rex' at a light intensity of 300 $\mu mol \cdot m^{-2} \cdot s^{-1}$. Fresh mass was greatest for both cultivars at day/night temperatures of 82/70 °F and CO_2 concentrations of 800 $\mu mol \cdot mol^{-1}$ for 'Rouxaï' and both 800 and 1200 $\mu mol \cdot mol^{-1}$ for 'Rex'.
- M.S. student Sean Tarr and Roberto Lopez modelled the response of kale and red oakleaf and green butterhead lettuces at day and night temperatures of 52/41 to 97/86 °F. The greatest leaf unfolding of 'Rouxaï' and 'Rex' occurred at 79/70 °F. However, fresh mass of 'Rouxaï' and 'Rex' was greatest at 88/77 °F and 79/68 °F, respectively. Kale had the greatest fresh mass at 70/59 °F, but had the greatest leaf number at 97/86 °F.
- Ph.D. student Eric Stallknecht and Erik Runkle studied the effect of an experimental red-fluorescent greenhouse film that converts some of the blue and most of the green light

into red light on greenhouse- and indoor-grown lettuce. On average, the experimental film decreased the average light transmission by 25% compared to an un-pigmented control film. Despite lower light transmission, lettuce yield per plant increased by 5% to 20%, depending on cultivar. Butterhead lettuce had the greatest yield increase under the experimental red-fluorescent film.

- Ph.D. student Nathan Kelly and Erik Runkle quantified the interaction between day length and light intensity on the yield of two lettuce cultivars grown in an indoor vertical farm. The research results indicated that, at the same high daily light integral, a longer day length paired with a lower light intensity led to higher yields than a shorter day length and higher light intensity.
- Visiting scholar Viktorija Vaštakaitė-Kairienė, Ph.D. student Nathan Kelly, and Erik Runkle quantified the effects of light quality on lettuce yield, nutritional quality, and post-harvest quality preservation. Experimental results revealed that the color of light added to a white light background had varying effects on lettuce growth and nutritional quality. In general, white light plus blue or red light increased the concentration of nutritional metabolites before and after storage.

Impact statements

- We learned more about cultivar-specific responses to CO_2 concentrations, day and night temperatures, and light intensities for indoor farming of lettuce. This sets up for future studies to refine the growing parameters with a focus on crop quality within the environmental conditions that brought forth the greatest yield.
- We have 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.
- Advanced greenhouse glazing materials can change the transmission spectrum or absorb solar energy not useful for photosynthesis to generate electricity. In a single case study with a red-fluorescent film, we learned that the paradigm of increased light increases crop yield does not account for changes to the light spectrum. Thus, it is essential to continue research on how photoselective greenhouse materials influence crop growth and quality, while also considering potential impacts during light-limited times of the year.
- Michigan State University published a review paper on how changing the indoor lighting environment impacts quality attributes of leafy greens such as nutritional quality, taste, and leaf coloration. This paper provides an easily digestible, comprehensive review of recent research that industry professionals can use to develop lighting strategies to optimize production.
- The Michigan Greenhouse Growers Expo and Floriculture Research Alliance meeting delivered unbiased, research-based information to over 400 greenhouse growers, plus additional growers and marketers of vegetable and fruit crops.

Published written works

Scientific manuscripts

Craver, J.K., K.S. Nemali, and R.G. Lopez. 2020. Acclimation of growth and photosynthesis in petunia seedlings exposed to high-intensity blue radiation. J. Amer. Soc. Hort. Sci. 145:152–161.

Garcia, C. and R.G. Lopez. 2020. Supplemental radiation quality influences cucumber, tomato, and pepper transplant growth and development. HortScience 55:804–811.
Kelly, N. and E.S. Runkle. 2020. Spectral manipulations to elicit desired quality attributes of herbaceous specialty crops. Eur. J. Hortic. Sci. 85(5):339-343.
Kelly, N., D. Choe, Q. Meng, and E.S. Runkle. 2020. Promotion of lettuce growth under an increasing daily light integral depends on the combination of the photosynthetic photon flux density and photoperiod. Sci. Hort. (article 109565).
Kohler, A.E. and R.G. Lopez. 2021. Daily light integral influences rooting of herbaceous stem-tip culinary herb cuttings. HortScience 56:432–438.
Kohler, A.E. and R.G. Lopez. 2021. Duration of light-emitting diode (LED) supplemental lighting providing far-red radiation during seedling production influences subsequent time to flower of long-day annuals. Scientia Hort. 281:1–11.
Kohler, A.E. and R.G. Lopez. 2021. Propagation of herbaceous unrooted cuttings of cold-tolerant species under reduced air temperature and root-zone heating. Scientia Hort. 281:1–11.
Lopez, R.G., Q. Meng, and E.S. Runkle. 2020. Blue radiation signals and saturates photoperiodic flowering of several long-day plants at crop-specific photon flux densities. Scientia Hort. 271:1–5.
Manjot, K.S., R.G. Lopez, S. Chaudhari, and D. Saha. 2020. A review of common liverwort control practices in container nurseries and greenhouse operations. HortTechnology 30:471–479.
Meng, Q. and E.S. Runkle. 2020. Growth responses of red-leaf lettuce to temporal spectral changes, Front. Plant Sci. 11:571788.
Meng, Q., J. Boldt, and E.S. Runkle. 2020. Blue radiation interacts with green radiation to influence growth and predominantly controls quality attributes of lettuce. J. Amer. Soc. Hort. Sci. 145:75-87.
Shen, L., R. Lou, Y. Park, Y Guo, E.J. Stallknecht, Y. Xiao, D. Rieder, R. Yang, E.S. Runkle, and X. Yin. 2021. Increasing greenhouse production by spectral-shifting and unidirectional light-extracting photonics. Nat. Food 2:434–441.
Vaštakaitė-Kairienė, V., N. Kelly, and E.S. Runkle. 2021. Regulation of the photon spectrum on growth and nutritional attributes of baby-leaf lettuce at harvest and during postharvest storage. Plants 10(3):549.
Walters K.J. and R.G. Lopez. 2021. Modeling growth and development of hydroponically grown dill, parsley, and watercress in response to photosynthetic daily light integral and mean daily temperature. PLoS ONE 16(3): e0248662.
Walters, K.J., B.K Behe, C.J. Currey, and R.G. Lopez. 2020. Historical, current, and future perspectives for controlled environment hydroponic food crop production in the United States. HortScience 55:758–767.
Walters, K.J., R.G. Lopez and B.K. Behe. 2021. Leveraging controlled-environment agriculture to increase key basil terpenoid and phenylpropanoid concentrations: The effects of radiation intensity and CO_2 concentration on consumer preference. Front. Plant Sci. 11:1–12.
Zhang, M., Y. Park, and E.S. Runkle. 2020. Regulation of extension growth and flowering of seedlings by blue radiation and the red to far-red ratio of sole-source lighting. Sci. Hort. (article 109478).

Trade articles

Frantz, J. and E. Runkle. 2020. Early scaling-up challenges with LED lighting. Greenhouse Product News 30(12):34.

Kohler, A.E. and R.G. Lopez. 2020. How adding far-red radiation to supplemental lighting affects plugs. Greenhouse Grower 38(12):61–62.

Kohler, A. and R. Lopez. 2021. Producing high-quality liners with root-zone heating. Grower Talks 85(10):56–60.

Kohler, A. and R. Lopez. 2021. Rooting cold-intermediate and cold-sensitive greenhouse crops. Grower Talks 85(11):58–62.

Kohler, A.E. and R.G. Lopez. 2020. Rooting herb cuttings: why daily light integral matters. Produce Grower 15–20.

Kohler, A., N. Durussel, and R. Lopez. 2021. Keys to rooting success. Greenhouse Product News 32(7):16−18.

Lopez R.G. 2021. Do micro drenches on annuals and perennials work? Greenhouse Grower 39(5):16–18.

Lopez R.G. 2021. Using and maintaining high-pressured sodium lamps in greenhouses. Produce Grower. 20–24.

Lopez, R.G. 2021. Meet the researchers: Introducing the new crop of CEA assistant professors. InsideGrower 14−15.

Lopez R.G. 2021. Meet the researchers: Part 2. InsideGrower 16−17.

Lopez R.G. 2021. What's all the hype on poinsettia micro-drenches? GrowerTalks 85(1):52−53.

Lopez, R.G. and C. Garcia. 2020. Beyond red and blue radiation: Explore the efficacy of LED supplemental lighting for high-wire vegetable transplants. Produce Grower 18–21.

Lopez R.G. and C. Garcia. 2021. Culinary herbs: To flower or not to flower? Produce Grower. 20–24.

Lopez, R.G. and E.S. Runkle. 2021. Making sense of light sensors. Greenhouse Product News 31(2):28−30.

Meng, Q. and E. Runkle. 2021. Far-red and PPFD: A tale of two lettuce cultivars. Produce Grower Oct.:20-24.

Meng, Q. and E. Runkle. 2021. Differentiating broad spectra. Produce Grower Sept.:30-33.

Meng, Q. and E. Runkle. 2021. LEDs on lettuce: White light vs. red+blue light. Produce Grower June:24-28.

Runkle, E. and J. Byrne. 2020. The importance of plant diagnostics. Greenhouse Product News 30(4):34.

Runkle, E. and P. Fisher. 2021. Greenhouse sanitation decreases pest problems. Greenhouse Product News 31(2):42.

Runkle, E. 2021. Challenges of growing vertically in greenhouses. Greenhouse Product News 31(6):42.

Runkle, E. 2020. Common plant production acronyms. Greenhouse Product News 30(5):42.

Runkle, E. 2020. Effective long-day lighting fixtures. Greenhouse Product News 30(11):42.

Runkle, E. 2020. Greenhouse energy efficiency tips. Greenhouse Product News 30(10):42.

Runkle, E. 2020. Height control of perennials: What works and what doesn't. Greenhouse Product News 30(8):50.

Runkle, E. 2021. "Hidden" benefits of supplemental lighting. Greenhouse Product News 31(4):42.

Runkle, E. 2020. How to produce poor-quality floriculture crops. Greenhouse Product News 30(9):50.
Runkle, E. 2021. Increasing the daily light integral. Greenhouse Product News 31(8):50.
Runkle, E. 2020. Indoor propagation. Greenhouse Product News 30(7):42.
Runkle, E. 2020. LED fixture efficacy: A 2020 update. Greenhouse Product News 30(1):50.
Runkle, E. 2021. Light fixtures and their photon fluxes. Greenhouse Product News 31(5):58.
Runkle, E. 2021. Light spectrum for different applications. Greenhouse Product News 31(9):58.
Runkle, E. 2021. Maximizing photosynthesis, minimizing respiration. Greenhouse Product News 31(3):42.
Runkle, E. 2021. More than µmol×J–1. Greenhouse Product News 31(7):42.
Runkle, E. 2021. Purpling of leaves. Greenhouse Product News 31(1):50.
Runkle, E. 2021. Strategies to shorten crop production time. Greenhouse Product News 31(10):42.
Runkle, E. 2020. The perils of low (greenhouse) temperature. Greenhouse Product News 30(2):42.
Runkle, E. 2020. UV-transmitting greenhouse glazing. Greenhouse Product News 30(6):42.
Runkle, E. 2020. What is the ideal lighting spectrum? Greenhouse Product News 30(3):42.
Spall, C. and R.G. Lopez. 2021. Manipulating daylength and light intensity top improve the greenhouse crop production of specialty crops. The Cut Flower Quarterly 33(3):20−22
Walters, K.J. and R.G. Lopez. 2020. Indoor production of herb seedlings: Light intensity and carbon dioxide. Produce Grower:20−24.