2020 Station Report

Purdue University

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New Facilities and Equipment.

Minitron. The Minitron III system for hydroponic growth, LED lighting, CO_2 control, and gas-exchange monitoring of crop-stand dynamics within a growth area of 0.41 m^2 was brought online in the C.A. Mitchell lab at Purdue University after an extended period of design, fabrication, testing, calibration, and upgrades. Progress during the past reporting period was sponsored by an AFRI project. Minitron III utilizes an open system of gas exchange, beginning with a high-capacity blower that delivers air at controlled flow rates through or around a humidification column and into the adjustable volume of a crop-growth/cuvette space sealed on the bottom against a hydroponic cropping surface and on the top against an overhead LED array. The side walls of the cuvette are of an accordion design that accommodates changes in separation distance between the mobile LED array and stationary crop stand, and therefore accommodates adjustable cuvette volume as well. Gas-flow options include scrubbing of CO_2 from air prior to the inlet port on the cuvette, injection of pure CO_2 through a mass-flow control valve (MFV) into the inlet air stream, scrubbed or unscrubbed, and controlled airflow rate of humidified or non-humidified air through the inlet port into the cuvette headspace through a larger MFV. Inlet air is delivered via an L-shaped distribution manifold into the cuvette space where two adjustable-angle fans mix inlet air turbulently with cuvette air being processed photosynthetically by plants in the light. An outlet port on the opposite side of the cuvette space vents excess, mixed cuvette air into a well-ventilated growth room housing Minitron III while a separate outlet draws representative air at a low controlled flow rate out of the cuvette space through a gas-routing board (GRB) and ultimately through an infrared gas analyzer (IRGA, Li-Cor 7000). A slipstream of pre-inlet air bypasses the cuvette and goes directly to the GRB and IRGA as a reference stream to determine photosynthetic drawdown of CO_2 by the contained, growing crop stand. CO_2 uptake by plants is corrected for mole-fraction differences in water vapor between sample and reference air streams.

YETI. The LED array sealed to the top of the cuvette side walls is an OSRAM creation custom-designed to our needs and requirements. It has four channels of red, blue, green, and far-red LEDs independently dimmable by waveband, as well as being on/off switchable by individual engine. It self-monitors electrical power (kW) and energy (kWh) consumption by two fixture fans and 48 LED engines when energized. Light engines on the array have been positioned directly above each plant-holder space on the hydroponics lid, and each light engine has removable secondary-optic lenses that can be used during targeted-lighting studies, or not used during complete-coverage-lighting studies. An RGB video camera mounted in the middle of the overhead array (instead of a central light engine) provides real-time overhead images of crop stands at all stages of growth and canopy closure, and daily screen-shot images are used as a living growth curve to monitor the progress of crop development and canopy closure. The OSRAM-developed LED array has been dubbed YETI, which stands for "Yield-Enhancement Technical Instrumentation".

Sensors. Lining the cropping surface between hydroponic plant holders is copper tubing through which water flows from and back to a temperature-controlled water bath located exterior to the walk-in growth chamber housing Minitron III. The copper tubing serves as a heat-exchange surface to maintain desired cuvette temperature in the light and prevent greenhouse-effect heating when YETI is energized. Three light-shielded thermocouples (TCs) and an Apogee PAR-FR sensor are mounted at crop level in the cuvette space. The PAR-FR sensor is periodically re-calibrated with a spectroradiometer to ensure accuracy of YETI photosynthetic photon flux density (PPFD), total photon flux density (TPFD), and spectral composition for each new light treatment applied. Another RGB video camera with pan-&-tilt adjustment capabilities is mounted in one corner of the cuvette that gives an image of the crop stand from the side, including height of the stand, which cannot be determined from overhead images in the closed cuvette.

Monitoring and Control. Sensor outputs are directed through signal conditioners, as required, to a central command & control (C&C) computer located exterior but adjacent to the walk-in growth chamber housing Minitron III. Signal outputs from the TCs, PAR-FR, IRGA, MFVs, and YETI are directed to the C&C computer. YETI operational software also has been loaded onto the C&C computer, and YETI lighting parameters are controlled from that computer. Original control of inputs and monitoring of outputs was established using the $C^{\#}$ programming language. However, the programming language was recently translated into the Python language for robustness of programming and stability of program running. Presently, the C&C computer reports 11 output or performance parameters including one data point per parameter every second over the course of an entire cropping cycle, which is 28-30 days for leaf lettuce. These parameters include CO_2 and H_2O*v* concentrations in both bypass and sample lines, as well as the differential CO_2 and H_2O*v* concentration between bypass and sample lines, temperature readings of three thermocouples, inlet flow rate, and IRGA barometric pressure. Gas-exchange differentials not only are tabulated digitally in streaming format, but also are presented graphically over a running 24-hour time span to facilitate near-term planning regarding changes to environmental treatments such as inlet CO_2 concentration, inlet flow rate, PPFD and/or TPFD, spectrum, or temperature in the light. During dark periods, the external water bath automatically switches off and thermal controls of the walk-in growth room housing Minitron III are programmed to control dark-temperature treatments within the cuvette.

New Controls for a High-Bay Controlled-Environment Walk-In Growth Chamber. As part of an SCRI project, an EGC high-bay walk-in growth room installed in 2006 received a C-6 control-system upgrade during the reporting period. The upgrade included touch-screen controls for all major environmental parameters, the most important of which for the near-term include day/night temperature, humidity, and CO_2 concentration. This growth chamber is equipped with a WMA-5 CO_2 gas analyzer to accommodate CO_2 concentration control and monitoring.

Adjustable-height, dimmable lighting system for bottom-fertigated baby-green tray culture. Within the refurbished high-bay growth chamber, four adjustable-height aluminum shelving frameworks were constructed with four vertically movable OSRAM Phytofy LED arrays, each consisting of three fixtures mounted above each stationary shelf holding four standard 20” x 10” plastic plant-growth trays. Computer controls for each daisy-chained lighting unit are located outside the growth chamber, and power/energy meters are connected to each set of three LED arrays above a given shelf. Up to 16 plant trays are being grown simultaneously comparing four different close-canopy lighting treatments, with or without fixture dimming, and/or testing different species or cultivars of greens crops with simultaneous energy measurements. One crop type will be tested at a time, focusing on determination of optimum separation lamp/tray-separation distance with minimal energy expenditure

Unique Plant Responses. Preliminary to the close-canopy lighting studies ongoing in the refurbished high-bay plant-growth chamber, fiber mats were investigated as a potential double-tray-based cultivation system with bottom fertigation for baby greens production based upon similar success with micro-greens. Commercial mats made from bamboo and/or hemp fiber were tested for growth of lettuce, arugula, kale, and mizuna in a standardized climate-control room. Preliminary findings were that baby-green crop stands of the above test species were labor-intensive for fertigation with non-uniform seedling growth, evaporative chilling from the wet mat surface, and non-toxic but unsightly algal growth on mats, possibly competing with plants for nutrients. Mizuna actually did the best of species tested followed by lettuce. Arugula and kale did not perform well in mat culture taken to the baby-green level of maturity (first set of true leaves expanding). Non-uniformity of hemp matting from one commercial source to another also appeared to be a cause for seedling non-uniformity of growth. Pelleted seed, which is the only available form for some greens species, did not respond well to the mat-growing system. Investigation of fiber mats as a growth medium for baby greens has been suspended in favor of a soilless-medium-based method of tray cultivation with bottom fertigation.

Accomplishment Summaries. Two research technical capabilities have been brought online during the reporting period, and both are expected to greatly enhance future capability to gather data for controlled-environment crop responses to different energy-saving treatments, including close-canopy lighting, targeted lighting, and those, in turn will open up unique opportunities for phasic optimization involving those lighting approaches. The Minitron III plant-growth/gas-analysis system will allow investigators to make real-time informed decisions regarding next-steps in growth-environment adjustment that will affect crop responsiveness to lighting, CO_2, and/or temperature conditions affecting energy-use efficiency. The refurbished-chamber close-canopy-lighting system is expected to greatly expand capability to simultaneously test effects of different light/crop separation distances on crop response with or without energy or PPFD standardization, and expand capability to compare responses of a variety of species and cultivars. Phasic-optimization treatment comparisons also can be greatly expanded using both systems. A cadre of undergraduate student helpers from the Purdue Polytechnic institute working together with students from the schools of Science and Agriculture have received valuable experience and training in multi-disciplinary controlled-environment-agriculture engineering and research during the reporting period. These experiences will influence their future professional choices for occupations.

Impact Statements. TBD next reporting period.

Published Written Works.

Burgner, S.E., K. Nemali, G.D. Massa, R.M. wheeler, R.C. morrow, and C.A. Mitchell. 2020. Growth and photosynthetic responses of Chinese cabbage (*Brassica rapa* L. cv. Tokyo Bekana) to continuously elevated carbon dioxide in a simulated Space Station “Veggie” crop-production environment. Life Sciences in Space Research 27: 83-88. doi.org/10.1016/j.lssr.2020.07.007

Sheibani, F., Z. H. Yu, A. Clemente, C. McDonnel, C. A. Mitchell. 2020. Monitoring the dynamics of leafy vegetable production in real time with the Minitron III crop-growth/gas-exchange system. American Society for Horticultural Science (ASHS) Conference. Poster presentation.