2023 NCERA-101 STATION REPORT

**Controlled Environment Systems Research Facility**
University of Guelph, Ontario Canada.
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**New Facilities and Equipment**

- Two PS1000 growth chambers were relocated from our satellite laboratory at Vivo Cannabis in Napanee, Ontario to our Guelph facility where they have joined their existing PS1000 kin.
- We received 22 Intravision Aurora 4-channel multispectral LED arrays with individual control on white, blue, far red and UV wavelengths. They have been deployed in a number of walk-in growth chambers where they have taken over from the original T12 lighting systems.
- GoodLeaf Farms donated 24 Philips Greenpower LED Production 2.1 modules (DR/B/FR 150) to our program.
- Two Flashforge Dreamer 3-D printers were added to our sensor development laboratory.
- Four bigfoot series Biochambers (originally T5 tubes) were retrofitted with ballast-compatible LED tubes (R/B/WW/CW/independent FR fixtures) to achieve various programable time-of-day light quality treatments.
- Two walk-in growth chambers were renovated and licenced for drug-type cannabis production research.

**Accomplishment Summaries**.

- A team of HQP supported with senior staff have advanced to Phase 2 of the Canadian Space Agency and Impact Canada Deep Space Food Challenge with their entry “Canada GOOSE (Growth Options for Outer Space Environments)”. This National contest aims to find new ways to grow food in space and runs in parallel with the NASA DSFC.
- Graham Co-Chaired the Canadian arm of the Deep Space Food Challenge and served as an international judge on NASA’s arm.
- With support from Chivas Brothers Ltd and Aegis Aerospace, Inc. the CESRF sent barley seeds to ISS where they were exposed to the harsh space environment for 338 days on the Materials International Space Station Experiment (MISSE) platform. Somewhat surprisingly, seeds exposed to the full vacuum of space were successfully germinated in the lab after their return. An additional seed package exposed to the cushier internal space station environment were returned to their Scottish home where they will be grown out and used to produce a single malt Scotch from the “Space-side” region.
- UoG was the lead (Graham as PI) for the Canadian Space Agency’s Food Production Topical Team (FPTT). The FPTT provided recommendations and guidance on how the CSA should advance Lunar plant production while advancing CEA technology for terrestrial needs.
- Secured a 5-yr research grant to advance CEA production of medicinal and high value crops
- Received a grant to develop lunar food production concepts (with McGill & Canadensys)
- Completed a lunar lander plant production concept design study (Lunar Exploration Agriculture Feasibility (LEAF)) also with McGill and Canadensys.
- Generated some urgently needed new knowledge for indoor cannabis production and published the ***Handbook of Cannabis Production in Controlled Environments***

***Technology transfer***:

- Our laboratory has collaborated with local vertical farm industries to assist with substrate selection, waste composting, LED deployment and selection of spectra for specific commodities.
- Genoptic Inc. has contracted the Grodzinski team at U of G along with Queens University (Kingston, ON Canada) and supplied the team with their newest programmable LEDs to develop and validate a novel AI-plant biofeedback system based.
- Continued to develop and advance patents of electrochemical water treatment technologies

***Communication***:

Tomatosphere™, a free science outreach program available throughout North America, is now in its 21st year, and has engaged over 4 million students since its inception. The program is designed for students from kindergarten to grade 12 and allows classes to investigate the effects of space on seed germination and ultimately contribute to human space travel.

Numerous presentations to student groups on CEA and bioregenerative life-support (e.g., Students for the Exploration and Development of Space (SEDS); multiple 'space challenge' grade school groups)

## Published Written Works since our last report

### Book Chapters

Stasiak M. and Dixon M. 2022. Growing Facilities and Environmental Control. In Zheng Y. (Ed.) Handbook of Cannabis Production in Controlled Environments. Boca Raton: CRC Press/Taylor & Francis.

Zheng Y. and Llewellyn D. 2022. Lighting and $CO_2$ in cannabis cultivation. In Handbook of Cannabis Production in Controlled Environments, ed. Y. Zheng. Boca Raton and London: CRC Press, Taylor & Francis.

Zheng Y. 2022. Rootzone management in cannabis cultivation. In Handbook of Cannabis Production in Controlled Environments, ed. Y. Zheng. Boca Raton and London: CRC Press, Taylor & Francis.

### Peer reviewed publications

Dsouza, A., Kiselchuk, C., Lawson, J. A., Price, G. W., Dixon, M., & Graham, T. 2022. Development of an automated, multi-vessel respirometric system to evaluate decomposition of composting feedstocks. *Biosystems Engineering*, *224*, 283–300. https://doi.org/10.1016/J.BIOSYSTEMSENG.2022.10.014

Gu L., Grodzinski, B., Han, J., Marie, T.R.J.G., Zhang Y-J., Song, Y.C., and Sun, Y. 2023. An exploratory steady-state redox model of photosynthetic linear electron transport for use in complete modelling of photosynthesis for broad applications. Plant Cell and Environment. Pre-published-online. https://doi.org/10.1111/pce.14563

Gu L., Grodzinski, B., Han, J., Marie, T.R.J.G., Zhang Y-J., Song, Y.C., and Sun, Y. 2022. Granal thylakoid structure and function: explaining an enduring mystery of higher plants. New Phytologist 236: 319-329. https://doi.org/10.1111/nph.18371

Haveman, N., Settles, A. M., Zupanska, A., Graham, T., Link, B., Califar, B., Callaham, J., Jha, D., Massa, G., Mcdaniel, S., Parmar, C., Tucker, R., & Wheeler, R. (n.d.). Elevating the Use of Genetic Engineering to Support Sustainable Plant Agriculture for Human Space Exploration A Topical White Paper for Submission to the Primarily Authored By Co-Authors (listed alphabetically). *Biological and Physical Sciences in Space Decadal Survey*, 2023–2032.

Kong Y. and Zheng Y. 2022. Low-activity cryptochrome 1 plays a role in promoting stem elongation and flower initiation of mature *Arabidopsis* under blue light associated with low phytochrome activity. Canadian Journal of Plant Science. https://doi.org/10.1139/CJPS-2021-0122.

Kong Y. and Zheng Y. 2022. Phytochrome contributes to blue-light-mediated stem elongation and flower initiation in mature *Arabidopsis thaliana* plants. Canadian Journal of Plant Science. 102(2). https://doi.org/10.1139/cjps-2021-0018.

Lemay J, Zheng Y, and Scott-Dupree C. 2022. Factors influencing the efficacy of biological control agents used to manage insect pests in indoor Cannabis (*Cannabis sativa*) cultivation. Front. Agron. 4:795989. doi: 10.3389/fagro.2022.795989

Lévesque, S., Graham, T., Bejan, D., Lawson, J., & Dixon, M. (2023). Prevention of Phytotoxic Effects of Regenerative In Situ Electrochemical Hypochlorination in Recirculating Hydroponic Systems. *HortScience*, *58*(1), 107–113. https://doi.org/10.21273/HORTSCI16734-22

Lévesque, S., Graham, T., Bejan, D. & Dixon, M. 2022. Comparative analysis of conventional and novel water treatment technologies for growing ornamental crops with recirculating hydroponics. Agricultural water management, 269:107673. https://doi.org/10.1016/j.agwat.2022.107673

Llewellyn D,. Shelford T, Zheng Y and Both A.J. 2022. Measuring and reporting lighting characteristics important for controlled environment plant production. Acta Horticulturae. 1337: 255-264. DOI 10.17660/ActaHortic.2022.1337.34

Llewellyn, D, Golem, S, Foley, E, Dinka, S, Jones, AMP and Zheng Y. 2022. Indoor grown cannabis yield increased proportionally with light intensity, but ultraviolet radiation did not affect yield or cannabinoid content. Frontiers in Plant Science 13:974018. https://doi.org/10.3389/fpls.2022.974018

Llewellyn D, Golem S, Jones M and Zheng. 2023. Foliar symptomology, nutrient content, yield, and secondary metabolite variability of cannabis grown hydroponically with different single-element nutrient deficiencies. Plants 12 (3), https://doi.org/10.3390/plants12030422

Marie, T.R.J.G., Leonardos, E.D., Lanoue, J., Hao, X., Micallef, B.J. and Grodzinski, B., 2022. A Perspective Emphasizing Circadian Rhythm Entrainment to Ensure Sustainable Crop Production in Controlled Environment Agriculture: Dynamic Use of LED Cues. Front. Sustain. Food Syst. 6: 856162. https://doi: 10.3389/fsufs.

Moher M, Llewellyn D, Jones M, and Zheng Y. 2022. Light intensity can be used to modify the growth and morphological characteristics of cannabis during the vegetative stage of indoor production. Industrial Crops and Products. 183. https://doi.org/10.1016/j.indcrop.2022.114909.

Moher M, Llewellyn D, Golem S, Foley E, Dinka S, Jones M and Zheng Y. 2023. Light spectra have minimal effects on rooting and vegetative growth responses of clonal cannabis cuttings. HortScience. 58 (2). https://doi.org/10.21273/HORTSCI16752-22.

Pepe, M., Leonardos, E.D., Marie, T.R.J.G.*, Kyne, S.T., Hesami, M., Jones, A.M.P., and Grodzinski, B. 2022. A non-invasive gas exchange method to test and model photosynthetic proficiency and growth rates of in vitro plant cultures: Preliminary implication for *Cannabis sativa* L. Biology. 11(5), 729. https://doi: 10.3390/biology11050729.

Pepe, M., Marie, T.R.J.G., Leonardos, E.D., Hesami, M., Rana, N., Jones, A.M.P., and Grodzinski, B. 2022. Tissue culture coupled with a gas exchange system offers new perspectives on phenotyping the developmental biology of *Solanum lycopersicum* L. cv. 'Microtom'. Frontiers in Plant Science, Sec. Plant Physiology, Published 10 Nov. https://doi.org/10.3389/fpls.2022.1025477

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Stoochnoff, J., Johnston, M., Hoogenboom, J., Graham, T., & Dixon, M. A. 2022. Intracanopy lighting strategies to improve green bush bean (Phaseolus vulgaris) compatibility with vertical farming. Frontiers in Agronomy, 73.

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