INNOVATIONS IN LED LIGHTING FOR REDUCED-ESM CROP PRODUCTION IN SPACE.

G. D. Massa[1*], R. C. Morrow[2], C. M. Bourget[2] and C. A. Mitchell[1], [1]Purdue University, Department of Horticulture and Landscape Architecture, 625 Agriculture Mall Drive, West Lafayette, IN 47907-2010, [*]gmassa@purdue.edu, [2]Orbital Technologies Corporation, (ORBITEC), 1212 Fourier Drive, Madison, WI 53717.

Introduction: In controlled-environment crop production such as will have to be practiced at self-sustaining, crewed space bases, the single most energy-demanding aspect is electric lighting for plant growth, including energy costs for energizing lamps as well as for removing excess heat [1]. For multiple reasons, sunlight may not be a viable option as the sole source of crop lighting off-Earth. Traditional electric lamps for crop lighting also have numerous drawbacks for use in a space environment.

A collaborative research venture between the Advanced Life Support Crops Group at the NASA Specialized Center of Research and Training in Advanced Life Support (the ALS NSCORT) and the Orbital Technologies Corporation (ORBITEC) has led to the development of efficient, reconfigurable LED lighting systems that will support crop growth in a space-based crewed habitat. The LED lighting arrays were based on previous proof-of-concept work with intracanopy fluorescent lamps [2]. The light sources use printed-circuit red and blue LEDs, which are individually tunable for a range of photosynthetic photon fluxes and photomorphogenic plant responses [3]. Initial lighting arrays have LED light engines that can be energized from the bottom upward when deployed in a vertical, intracanopy configuration, thereby allowing the illumination to be tailored for stand height throughout the cropping cycle (Fig. 1).

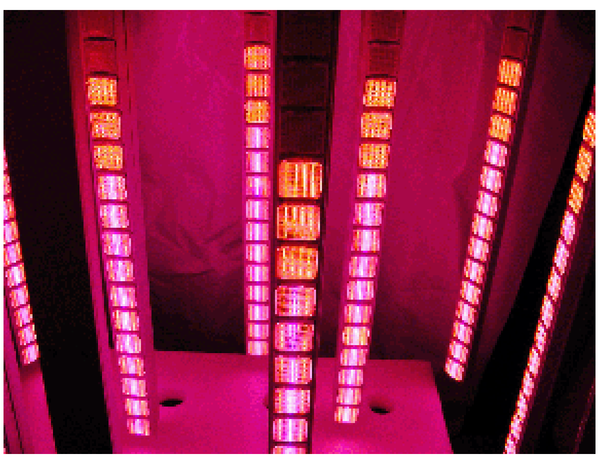

Fig. 1 Lighting array in an intracanopy configuration with red + blue or red alone LEDs energized.

Preliminary testing with the planophile crop cowpea (*Vigna unguiculata* L. Walp, breeding line IT87D-941-1), resulted in optimizing internal reflectance of growth compartments by lining growth-compartment walls, floor, and a movable ceiling with white Poly film, as well as by determining optimal planting density and plant positioning. Additionally, these individual light strips, called “lightsicles”, can be reconfigured into a continuous overhead plane of light engines [4].

When intracanopy and overhead-LED-lit cowpea crop production was compared, cowpea plants grown with intracanopy lighting had much greater understory leaf retention and produced more dry biomass per kilowatt-hour of lighting energy than did overhead-lit plants. The efficiency of light capture is reduced in overhead-lit scenarios due to mutual shading of lower leaves by upper leaves in closed canopies leading to premature senescence and abscission of lower leaves. One system modification has led to lightsicles of different lengths, allowing a wider array of intracanopy lighting configurations.

Another development is an adaptive system in which each light engine can be operated independently, and photodiodes can detect reflectance patterns off of leaves from flashing green LEDs, thereby indicating positions of leaves within the foliar canopy relative to any given light engine on a lightsicle. When this advanced hardware is coupled to tailored software, the reflectance can be used to auto-detect changes in plant growth and adjust the lighting accordingly. These lighting systems have been tested with cowpea, pepper (*Capsicum annuum* L. cv. Triton) and Lettuce (*Lactuca sativa* L. cv. Waldmanns Green, Fig. 2) with limited testing of other ALS candidate crop species.

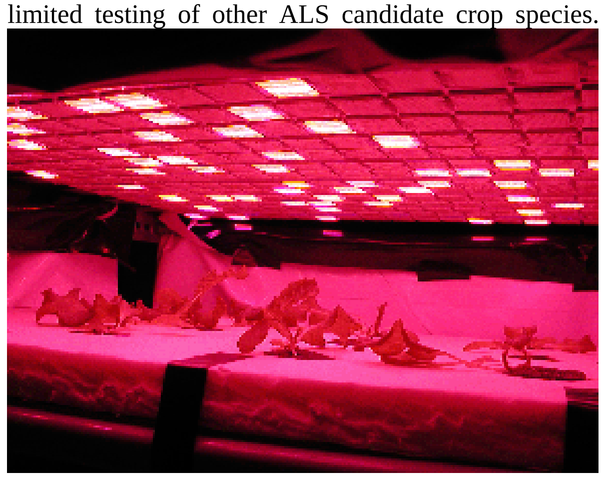

Fig. 2 Lettuce plants growing under an overhead con-

figuration of LED lights that have auto-detection and response capabilities.

The versatility of these LED lighting systems will allow energy-efficient light delivery to a wide variety of crops with different growth habits, including planophile, erectophile, and rosette species. This research has been supported by NASA grants NAG5-12686 (NSCORT) and NNK05OA20C (SBIR Phase 1) and NNK06OM01C (SBIR Phase 2).

References:

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