**Ankit K. Singh**

**Title**: Performance study of GREENBOX technology; a more resourceful avenue of crop production

**Abstract**: Food security and safety have been under threat from urbanization and the increasing global population, showing no sign of slowing down. Access to fresh, nutritious foods (especially leafy greens and vegetables) is increasingly arduous for the urban population due to expansions of food deserts and, consequently, increased food miles traveled. The Yang lab at the University of Connecticut has been developing the GREENBOX technology for the past four years, aiming to serve as a suitable, sustainable, and economically feasible food production system local to urban residents. GREENBOX can grow crops in individually climate-controlled boxes in an urban warehouse environment and consist of a thermally insulated modular structure with an artificial lighting source, hydroponic nutrient supply system, crop monitoring mechanism (such as a camera), and environmental controls. We have designed these GREENBOX's to be implemented at large-scale operations in warehouse conditions, which provide an avenue for repurposing abandoned structures such as warehouses, strip malls, and tunnels, which require minimal retrofitting.

To test the technical feasibility of the GREENBOX concept, we carried out pilot studies at the University of Connecticut, Storrs, Connecticut, by constructing two modular GREENBOX structures (using commercially available materials) for crop growth. We equipped each GREENBOX with an LED lighting system, NFT hydroponic system for nutrient delivery, and environmental monitoring and control systems in the headhouse of an experimental greenhouse (to simulate warehouse conditions with high ceilings and minimal natural lighting). Following a two-week seedling preparation period, we grew butterhead Rex lettuce (Lactuca sativa) in a 4x6 configuration (24 heads total in each GREENBOX) over a 30-day cycle.

We grew crops over four seasons (spring, summer, fall, and winter) to represent the varying growing conditions over the year in a temperate climate, such as Connecticut, defined by warm summers and cold winters. We quantified crop growth in biomass data (wet weight, dry weight, plant total leaf area, and projected leaf area index). The wet and dry weight and total leaf area data were obtained via destructive sampling every three days. We determined the projected leaf area index and total leaf area using image processing technology. Environmental data, including light, temperature, relative humidity, and carbon dioxide concentration, were collected and processed to a 15-minute average for analysis. We used a lysimeter to determine the water consumption rate by plants in the GREENBOXES, which we also used to infer evapotranspiration (data collected at 15-minute intervals).

Over the four seasons, data collected so far have indicated that the protocol GREENBOXES provided the desired environmental conditions for growing the crops at Storrs, Connecticut. The average light conditions averaged 125 W/m2 in the lettuce heads' height and were regulated at the grower's discretion. The mean inside temperatures was around 27 °C, falling within the optimal range (17-29°C) for lettuce production. The temperature was easily controlled by ventilation (the only heating source being the artificial lighting source). The average relative humidity was below 60%, within the desired range (50-70%) for lettuce. The $CO_2$ concentration inside the boxes fell slightly below the ambient concentration of 340 ppm, averaged 300 to 320 ppm in different seasons. We found that water consumption in the GREENBOXES varied differently amongst seasons but much less than operations in open fields or greenhouses (2.08-2.33 liters per head of lettuce). Lettuce plants were all healthy and growing to full size in the 30-day cycle, irrespective of seasons. The dry weight, wet weight, and

projected leaf area index followed similar water use patterns, varying slightly over seasons, and we noted that yields were marginally higher in warm seasons. Our results so far indicated that the GREENBOX technology has a high potential to be scaled up for food production in an urban environment at a large-scale setting.

**Keywords**: agricultural facility, environmental control, GREENBOX, Lettuce, urban agriculture, controlled environmental agriculture

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