Klover International Journal of Food Science and Nutrition
Volume 10 Issue 1, January-March 2022
ISSN: 2995-4517
Impact Factor: 5.54
https://kloverjournals.org/journals/index.php/fsn

HYDROPONIC SHOWDOWN: DWC VS. WICK SYSTEM FOR LETTUCE CULTIVATION

Benjamin Thomas Mitchell[1], Olivia Marie Reynolds[2]
Natural Resource Conservation Service, White Sulphur Springs, MT, United States
Eastern Kentucky University, Department of Agriculture, Richmond, KY, United States

Abstarct
As the global population burgeons and available farmland diminishes, the imperative to enhance food production efficiency becomes increasingly pressing (Fedoroff, 2015). Within this context, indoor and urban farming methodologies have emerged as viable solutions to augment agricultural output (Specht et al., 2014). A Market Analysis Report (2019) assessing the hydroponic market size underscores the sector's anticipated robust growth, with a projected compound annual growth rate of 20.7% from 2021 to 2028. This trend finds manifestation in urban landscapes, where disused structures are being repurposed into controlled environment facilities for food production through hydroponics and advanced LED lighting systems. Illustrative instances include the transformation of an abandoned steel mill into Aero Farms in Newark, New Jersey (Aerofarms, 2022), and the conversion of an erstwhile meat packaging plant into The Plant in Chicago, Illinois (Chance et al., 2017). While large-scale controlled environment hydroponic farming promises substantially higher yields on markedly reduced land footprints, the environmental ramifications and sustainability of these systems, encompassing factors like electricity consumption, necessitate careful consideration (Martin and Molin, 2019).

Keywords: Indoor Farming, Urban Agriculture, Hydroponics, Controlled Environment Agriculture, Sustainability in Agriculture

1. Introduction

The world population is increasing with less farmland to produce food to meet the demand (Fedoroff, 2015).Indoor and urban farming options are expanding as a solution to grow food more efficiently (Specht et al., 2014). According to a Market Analysis Report (2019) evaluating hydroponic market size, hydroponics are expected to have a global increase at a compound annual growth rate of 20.7% from 2021 to 2028.To illustrate this, cities have converted unused buildings to controlled environment food production systems using hydroponics and LED lights. Some examples include Aero Farms in Newark, New Jersey,(Aerofarms, 2022) where an abandoned steel mill was converted to hydroponic production and The Plant in Chicago, Illinois (Chance et al., 2017) uses an old meat packaging plant to grow food. Although large scale controlled environment hydroponic food production produces higher yields on much less land, the environmental performance and sustainability of these systems, including electricity demand, needs to be considered (Martin and Molin, 2019).
Growing food at home has become more popular over the past 15 years (Kortright and Wakefield, 2011; Libman, 2007; Lyle et al., 2015; Vitiello and Wolf-Powers, 2014), including the use of hydroponic systems. Resources are available to assist the public in using hydroponic systems at home (Jones, 2019; Resh 2013; Resh, 2015; Thatcher, 2016) including for those individuals who want to grow food indoors

year-round (Baras, 2021; Chiras and Zadere, 2022; Roman, K. 2022; Van Patten, 2008). However, many of the suggested hydroponic systems can be very expensive. Research is needed to evaluate the effectiveness of more cost efficient systems compared to commercially available hydroponic systems.

The objectives of this study were to: 1) Evaluate weekly growth of *Lactuca sativa* from a commercially available hydroponic system (Tower A) and from a student-designed and built hydroponic system(Tower B), and 2) Evaluate total yield harvested of *Lactucastaiva* from Tower A and Tower B after 50 days of treatment (DOT).

2. Materials and Methods

2.1 *Preparation and maintenance of hydroponic tower gardens*

Studies were conducted to evaluate performance of two hydroponic tower gardens. One study was conducted in the spring and a second in the fall of 2016. A commercially available Tower Garden FLEX Growing System (Tower Garden, 2022) from Juice Plus with the LED indoor grow light, support cage, extension kit, and dolly accessorywas evaluated against a tower garden designed and built by a student at Eastern Kentucky University (EKU). The commercially available tower garden (Tower A) consisted of a 120 L volume round nutrient solution reservoirthat supported a single 20 cm diameter pipe with 24 plant compartments evenly spaced throughout the tower. The student-designed and built tower garden (Tower B) was constructed with a 100 L volume rectangular storage tote used as a nutrient solution reservoir that supported two 10 cm diameter pipes with 12 evenly spaced plant compartments on each pipe. Pipes on Tower B were spaced 30 cm apart. All pipes on both towers A and B were 1.2 meters tall.The artificial lighting systems for both towers A and B included four lights that were spaced 19 cm from the plants. Each light on tower A and B measured 114 cm and 120 cm, respectively.

Seeding and establishment of Black Seeded Simpson lettuce, *Lactuca sativa*, for both studies was in 2.5 cm^3rockwool cubes under intermittent mist (15 seconds on and 10 minutes off) in a greenhouse prior to being transferred to each tower garden (A and B) in an indoor setting.Establishmentfor the spring study was from 18 March 2016 through 28 March 2016 with an average day/night air temperature was 25□C / 23□C. The average day/night air temperature was 26□C / 25□Cfor the fall study established from 23 September 2016 through 10 October 2016.

Ten days after seeding, seedlings were arranged in a randomized complete block design with three replications on each tower. The study took place in a room in the CRAFT (Center for Renewable and Alternative Fuel Technologies) building in Richmond, Kentucky (37□73'36" N, 84□30'08" W). The average day/night air temperature in the room was 20□C / 19□Cin the spring and 24□C / 23□C in the fall. Room light levels during both studies was 0.6 lm/ft^2 (FCM-10M+, Phytotronics, Inc., St. Louis, MO) of lighting without the grow lights on the tower gardens illuminated and 10.3 lm/ft^2 with the grow lights illuminated. The average light intensity at plant level was 373.46 lm/ft^2 on tower A and 255.25 lm/ft^2 on tower B. Flora Series solution (Flora Series, 2022), a 3part hydroponic based nutrient system, was used to provide nutrients for the lettuce in each tower. FloraGro (2-16) was used at a rate of 132 ml/100 L for DOT 1-7 and 396 ml/100 L for DOT 8-50, with the reservoir solution changed every 14 DOT.

2.2*Leaf area index and leaf weight*

Measurements of leaf area index (LAI) and leaf weight were taken weekly on DOT 9, 16, 23, 30, 37, 44, and 50. An average-sized leaf was selected and harvested from each container to measure LAI with a portable area meter (Model LI-COR 3000C, Lincoln, NE) and leaf weight to the nearest gram using an electronic balance (Model APX-100, Denver Instrument, Arvada, CO). At the conclusion of the study, DOT 50, lettuce was destructively harvested and total LAY and leaf weight recorded for each container.

2.3*Data analysis*

Weekly averages of LAI and leaf weight were calculated among towers A and B. Data were analyzed among towers using the general linear model (GLM) procedure in SAS as a randomized complete block design (SAS Institute, Cary, NC). Means were separated using Fisher's protected least significant difference (LSD) at *P*=0.05.

3. Results

There was significant interaction between the two studies; therefore, data from each study are presented separately. Both tower A and B had similar leaf area and leaf weight throughout each of the spring and fall studies with differences noted in LAI and leaf weight on DOT 16, 23 (spring and fall), and 37 (fall only) (Fig. 1 and 2). At the conclusion of each study (DOT 50), LAI and leaf weight were greater for Tower A (Fig. 3 and 4) with the exception of no differences being observed for LAI between the two towers at the end of the fall study (Fig. 3). Overall, both towers produced higher yields in the fall study compared to the spring study (Fig. 3 and 4). Tower A yielded 50% (LAI) and 42% (leaf weight) more lettuce in the fall than spring; and Tower B yielded 58% (LAI) and 27% (leaf weight) more lettuce in fall than spring.

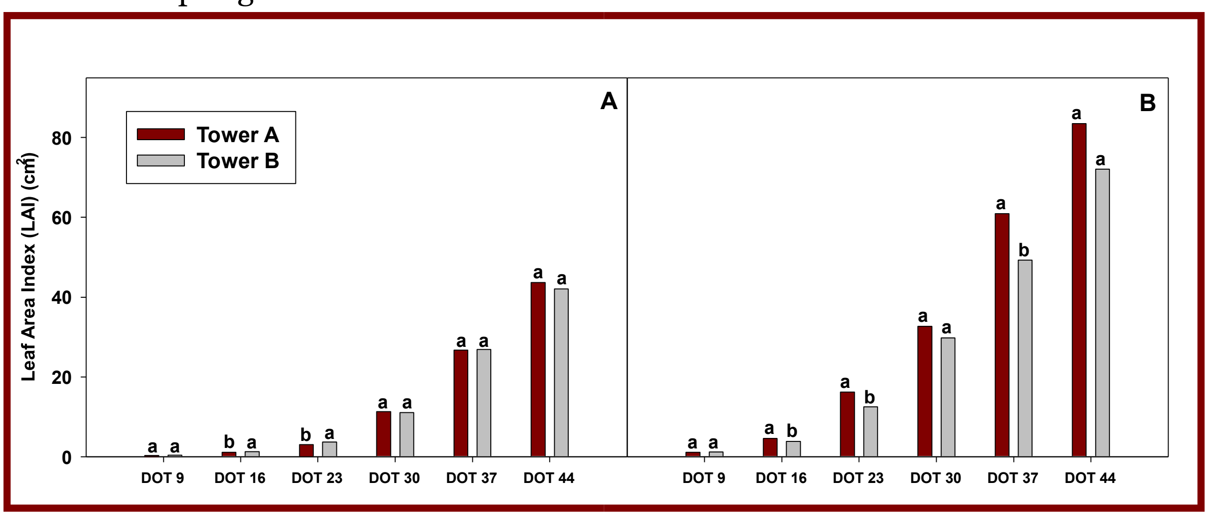

Fig. 1. LAI of each tower for DOT 9, 16, 23, 30, 37, and 44 of the spring (A) and fall (B) studies. One average-sized leaf from each compartment was destructively harvested and measured each week. Means followed by the same letter with each DOT are not significantly different (P=0.05).

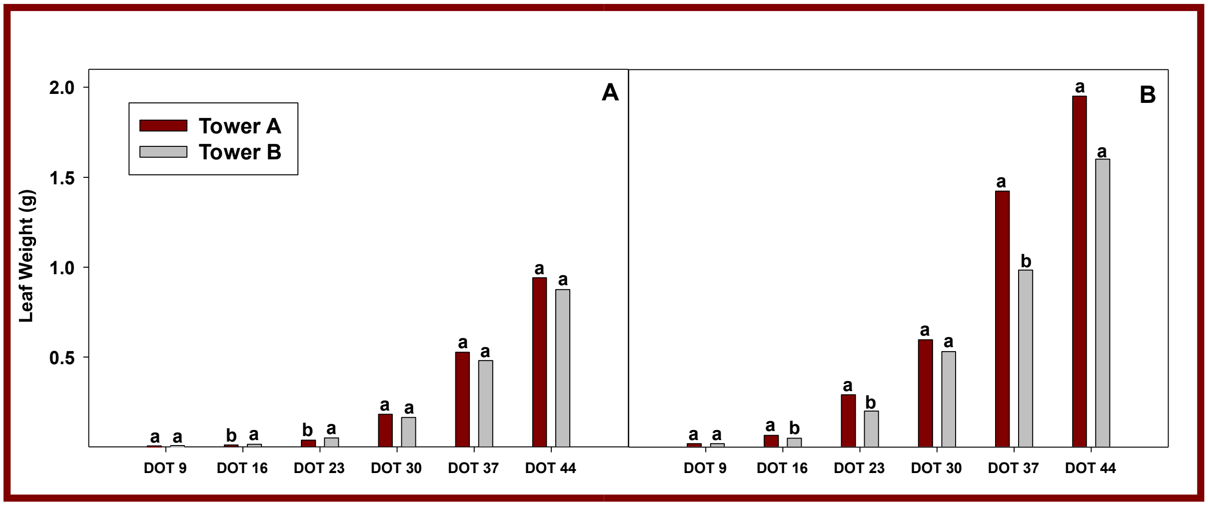

Fig. 2. Leaf weight of each tower for DOT 9, 16, 23, 30, 37, and 44 of the spring (A) and fall (B) studies. Once average-sized leaf from each compartment was destructively harvested and measured each week. Means followed by the same letter within each DOT are not significantly different (P=0.05).

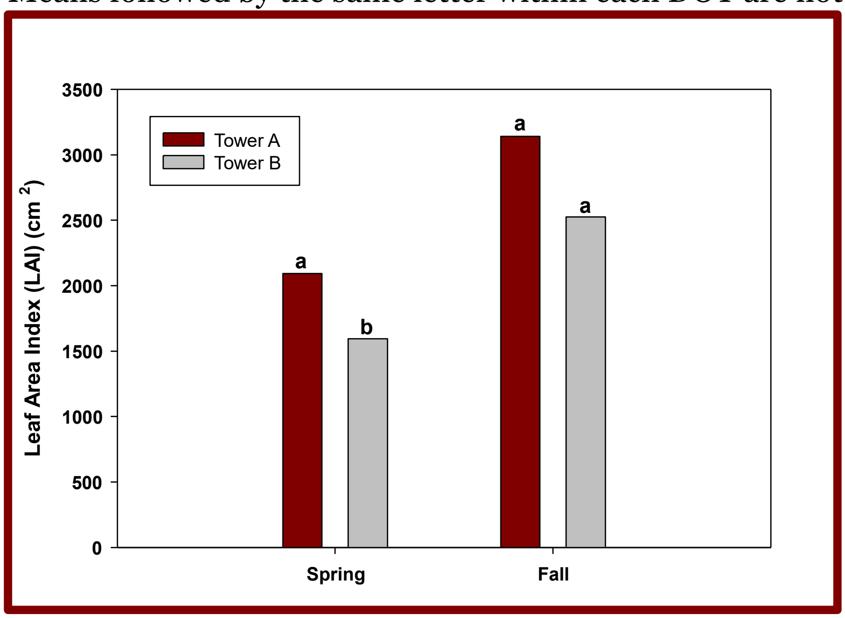

Fig. 3. LAI of each tower for DOT 50 of the spring and fall studies. All leaves (entire plant) from each compartment were destructively harvested and measured. Means followed by the same letter within each study are not significantly different (P=0.05).

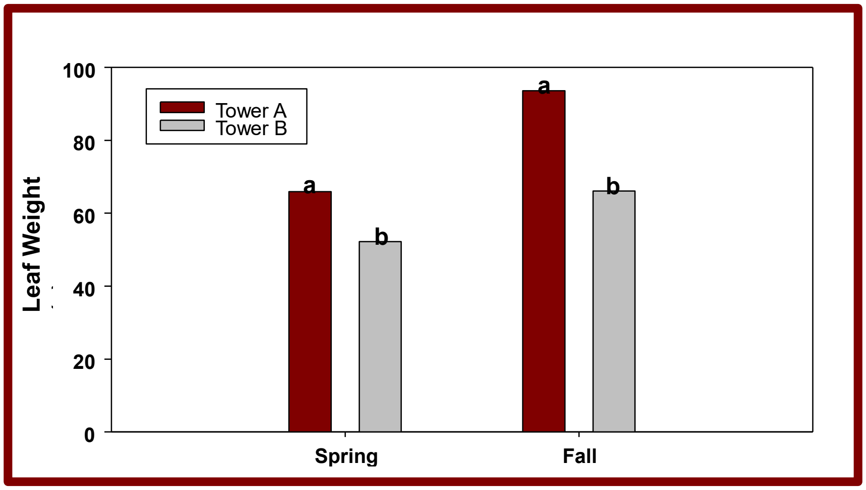

Fig. 4. Leaf weight of each tower for DOT 50 of the spring and fall studies. All leaves (entire plant) from each compartment were destructively harvested and measured. Means followed by the same letter within each study are not significantly different (P=0.05).

4. Conclusion

Weekly growth data indicates there are few significant differences between the effectiveness of the two towers to grow *Lactuca sativa*, although results are inconclusive because only one leaf was measured on DOT 9, 16, 23, 30, 37, and 44. Total yield data collected at the conclusion of each study (DOT 50) indicates Tower A performs better than Tower B when growing *Lactuca sativa*. Lower yields from Tower B may have been caused by lower light levels (118.21 lm/ft^2 lower on Tower B than Tower A) and poor light distribution causing light to not reach the lettuce located in the area between the two pipes. An increase in yields from spring to fall by both towers was likely caused by an increase in room temperature of 4□C both day and night. The minimal differences between the growth and yields of *Lactuca sativa* on both towers suggests the student-designed and built system (Tower B) produces similar results to the commercially available hydroponic system (Tower A).

5. References

Aerofarms. Aerofarms. 2022 [Online] Available: https://www.aerofarms.com/ (verified 29 July 2022)

Baras, T. 2021. Home hydroponics: small-space DIY growing systems for the kitchen, dining room, living room, bedroom, and bath. Quarto Publishing Group USA Inc.

Chiras, D. and V. Zadere. 2022. Grow lettuce in your living room. Wind River Publishers.

Federoff, N.V. 2015. Food in a future of 10 billion. Agriculture and Food Security 4:11.

"Flora Series." General Hydroponics. 2022 [Online] Available: https://generalhydroponics.com/products/floraseries/ (verified 22 July 2022).

Jones, N. 2019. Hydroponics for beginners: start growing vegetables at home without soil. Practicalgrowing.com.

Kortright, R. and S. Wakefield. 2011. Edible backyards: a qualitative study of household food growing and its contributions to food security. Agriculture and Human Values 28: 39-53.

Libman, K. 2007. Growing youth growing food: how vegetable gardening influences young people's food consciousness and eating habits. Applied Environmental Education and Communication 6:87-95.

Lyle, P., J. Choi, and M. Foth. 2015. Growing food in the city: design ideations for urban residential gardeners. C&T '15: Proceedings of the 7th International Conference on Communities and Technologies 89-97.

Market Analysis Report. 2019. Hydroponics market size, share and trends analysis report by type (aggregate systems, liquid systems), by crops (tomatoes, lettuce, peppers, cucumbers, herbs), by region, and segment forecasts, 2021-2028. [Online] Available: https://www.grandviewresearch.com/industryanalysis/hydroponicsmarket#:~:text=The%20global%20hydroponics%20market%20size,the%20indoor%20farming%20of%20vegetables (verified 29 July 2022).

Martin, M., and E. Molin. 2019. Environmental assessment of urban vertical hydroponic farming system in Sweden. Sustainability 11:4124.

Resh, H. M. 2013. Hobby hydroponics, second edition. CRC Press, Taylor and Francis Group.

Resh, H. M. 2015. Hydroponics for the home grower. CRC Press, Taylor and Francis Group.

Roman, K. 2022. How to garden indoors and grow your own food year round. Creative Homeowner.

Specht, K., R. Siebert, I. Hartmann, U. Freisinger, M. Sawicka, A. Werner, S. Thomaier, D. Henckel, H. Walk, and A. Dierich. 2014. Urban agriculture of the future: an overview of sustainability aspects of food production in and on buildings. Agriculture and Human Values 31:33-51.

Thatcher, T. 2016. Hydroponcis: hydroponics gardening guide from beginner to expert. Breakthrough Publishing.

"Tower Garden." Juice Plus. 2022. [Online] Available: https://www.towergarden.com/shop/tower-garden (verified 22 July 2022).

Van Patten, G. F. 2008. Gardening indoors with soil and hydroponics. Van Patten Publishing.

Vitiello, D., and L. Wolf-Powers. 2014. Growing food to grow cities? The potential of agriculture for economic and community development in the urban United States. Community Development Journal, 49:508-523.