AQUA≈360: Water for All - Emerging Issues and Innovations
1-3 September 2020, Exeter, United Kingdom

Investigation into how different methods of hydroponics using municipal wastewater improve crop growth

Dr. Dominic Clyde-Smith[1], Dr. Luiza C. Campos[1]
[1] Department of Civil, Environmental and Geomatic Engineering, University College London, WC1E 6BT, UK
[1]*ucesdrc@ucl.ac.uk*

Keywords: Hydroponics, Dissolved Oxygen, Sustainability, Wastewater, Urban farming

EXTENDED ABSTRACT

Introduction

Urban regions have limited land resources, inadequate energy supplies and growing water stresses, most of which is imported. This importation is used linearly, causing the value to be lost, particularly with food/nutrients. A solution could be vertical urban farming that mines this nutrient from the waste stream closing the loop. Hydroponics, a soilless method of agriculture, have traditionally been used to maximise crop yields by optimising the plant's roots access to nutrients and oxygen. This aspect helps the ecosystem of the rhizosphere, namely the microorganism, to utilise hydroponic technology to mine nutrients from wastewater which would be a solution for vertical urban farming.

From the literature, it can be concluded that wastewater can be treated by hydroponic systems to the standards required by legislation (Al-Karaki, 2011; Haddad & Mizyed, 2012; Rana, et al., 2011). The literature focuses on the Nutrient Film Technique (NFT). There are however other types of hydroponics. To developed a vertical system for nutrient mining it is important to understand how these different systems improve access of both oxygen and nutrients to the rhizosphere, to allow both maximum growths of the plant and treatment of the wastewater (Brix, 1997). This research aims to develop a hydroponic system that bio-mimics the treatment of wastewater by wetlands, as a part of vertical urban farm, utilising value crops. It was hypothesised that access to oxygen was the key limiting factor for the system and it was proposed that a hydroponic system would mimic wetlands' ability to provide oxygen to the rhizosphere.

Methods and Materials

There were six hybrids of the System: Geyser Pump (GP), Full Flow (FF), Ebbs and Flows, NFTs, aeroponics (AP) and MisTing (MT) (the fogponic unit) plus a Control (C), some are illustrated in Figure 1.

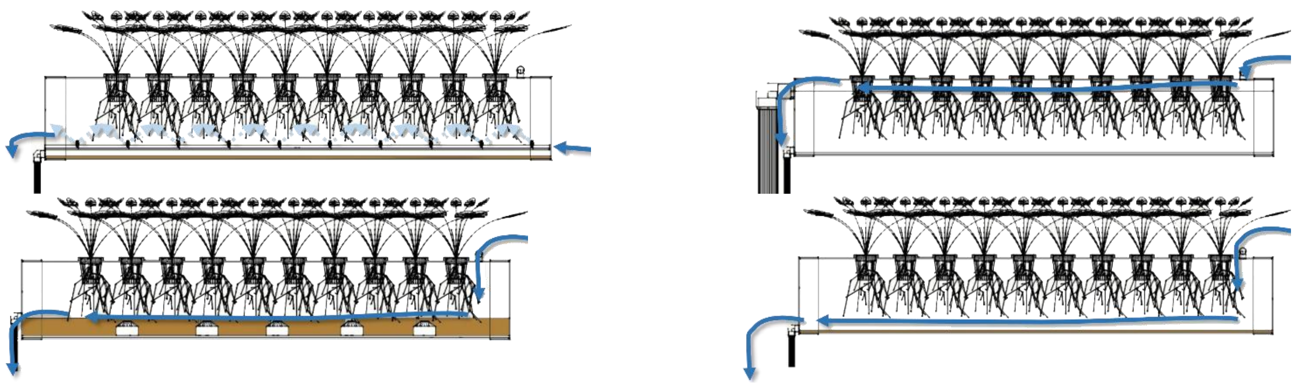

Figure 1. A cross-section of the different systems, AP top left, FF and EF top right, MT bottom left, and NFT bottom right

Each system was built using PVC waste pipe of 0.16 m diameter and 1 m in length. Each pipe had the capacity for 10 plants. Each system had a reservoir tank with a volume of 240L. The secondary wastewater was recirculated using a pump that runs constantly, apart from the EF pumps which run 15mins on/off. The experiment was run for a period (the Period) of 7 days and then repeated for another 7 days. Afterwards, the plants were replaced with the next species. All plants were measured and weighed at the start and end of the experiment. The experiment used secondary wastewater from Bellozanne sewage treatment works, in Jersey. At the start of the period the reservoir was filled with effluent. The effluent was recirculated, within the system from the reservoir, for a retention time of one week and was repeated. A standard wheelie bin (Vol = 240 L) was used as the reservoir. A pump resided at the bottom of the reservoir to which a feed pipe was attached. This pipe was attached to the opposite side of the system to that of its reservoir. The wastewater flowed down the pipe via its specific method of hydroponics and exited down the return pipe at the far end back into its reservoir. Samples were taken and analysied at 0 hrs, 24 hrs, 48 hrs, 72 hrs, and 120 hrs.

Results and Discussion

The experiments undertaken for tomatoes, rice, ivy, and wheat, were run for 7 days and then repeated. The plants were weighed and measured before and after the experiment runs, the result of which is illustrated in Figure 2.

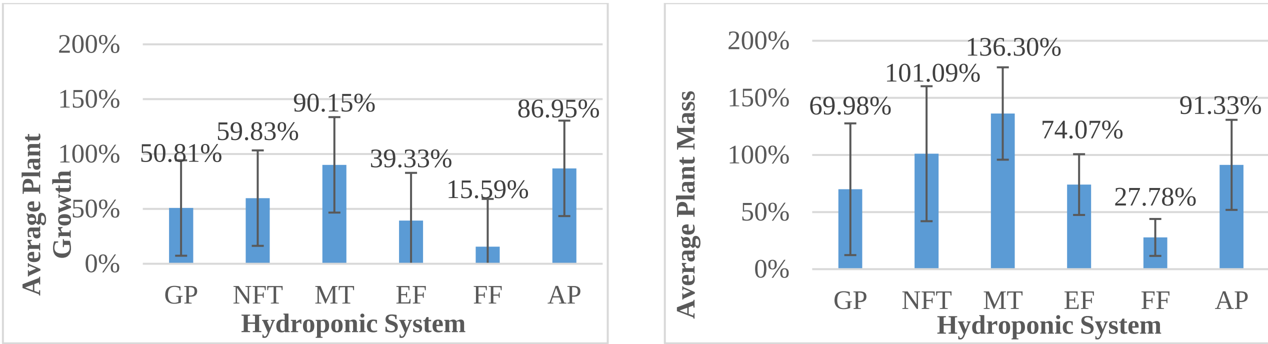

Figure 2. Average growth as a measurement of length (left) and mass (right) as a percentage for each system across all experiments

It can be seen from Figure 2 that there was a very significant growth ($P \leq 0.001$). The greatest growth was found in AP and MT systems, that both produced fine droplets allowing for greater access to oxygen. Roots need to breathe; unless flood-tolerant they need oxygen (Armstrong & Malcom, 2002). The dissolved oxygen (DO) was measured every 24 hours the results of which are shown in Table 1.

Table 1. The average change of the DO from the start until 1 day and the end (7 days), and the P-value of the t-Test where $P \leq 0.05$ was considered significant.

		C	GP	NFT	MT	EF	FF	AP
1 day	Increase DO	4.59%	53.65%	47.34%	46.02%	36.26%	41.11%	49.68%
	t-Test	0.13	$P \leq 0.05$	$P \leq 0.05$	$P \leq 0.05$	$P \leq 0.05$	$P \leq 0.05$	$P \leq 0.05$
7 days	Increase DO	4.59%	53.65%	47.34%	46.02%	36.26%	41.11%	49.68%
	t-Test	0.16	$P \leq 0.05$	$P \leq 0.05$	$P \leq 0.05$	$P \leq 0.05$	$P \leq 0.05$	$P \leq 0.05$

All the systems started with a low DO but over time there was a significant ($P \leq 0.05$) increase apart from the control which remained low. EF and FF had the lowest increase in biomass as the roots were flooded. AP and MT that allowed the roots to be in the air, but saturated with droplets, had the greatest growth. From this, it can be taken that the design of the vertical farming system needs to engineer these properties.

Conclusions

The overall conclusion that can be drawn from the experimentation is that the degradation of the organics and the health of root system and the subsequent growth of the plant is dependent on the adequate supply of oxygen to the root system as well as the symbiotic partner - the biofilm. In a constructed wetland system oxygen is not readily available. The plants used in constructed wetlands only survive these anoxic conditions as they have evolved to transport oxygen to the root system via aerenchyma, some of which will leak into the rhizosphere supporting some form of biofilm. On the other hand, in a hydroponic system, oxygen and DO are more freely available. Novel hydroponic system creates droplets allow for the greatest access to oxygen and nutrients allowing for the largest growth. The design of a vertical hydroponic urban farm needs to create the properties.

REFERENCES

Al-Karaki, G. N., 2011. Utilization of Treated Sewage Wasterwater for Green Forage Production in a Hydroponic System. *Food Agriculture,* 23(1), pp. 80-94.

Armstrong, W. & Malcom, D. C., 2002. Root Growth and Metabolism Under Oxygen Deficienc. In: 3, ed. *PLANT RooTS : THE HIDDEN HAL.* New York: Marcel Dekker, pp. 729-761.

Brix, H., 1997. Do Macrophytes Play a Role In Constructed Treatment Wetlands. *Water Science Technology,* 35(5), pp. 11-17.

Haddad, M. & Mizyed, N., 2012. Evaluation of various hydroponic techniques as decentralised wastewater treatment and reuse systems. *International Journal of Environmental Studies.*

Rana, S. et al., 2011. Reclamation of Municipal Domestic Wastewater by Aquaponics of Tomato Plants. *Ecological Engineering,* Volume 37, pp. 981-988.