Innovative Multi-stage Airlift Pump for Vertical Farming

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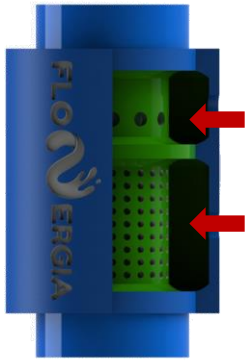
Introduction

With urbanization increasing at a rapid rate, vertical farming systems are becoming more relevant to fulfill the demand for fresh foods in increasingly smaller spaces [1]. When farming with no soil, plants not only need moisture, but they require nutrients in the form of small solid particles [1]. Additionally, plant roots have to be partially immersed in water, and have contact with air to achieve oxygenation [2]. Therefore, hydroponic systems require lifting a nutrient rich water solution and aeration to nourish and grow plants.

The airlift pump meets these two requirements with its ability to move liquids and aerate said liquids simultaneously. Airlift pumps are special effect pumps that utilize compressed gas to lift liquids or slurries, operating on the buoyancy effect [3]. Their simplistic and low maintenance design allows for handling of materials that would otherwise damage mechanical pumps. The dual injector airlift pump consists of two geometries: axial and radial.



Nutrients
Airlifts pump mixtures and slurries, can therefore pump required solid nutrient particles with ease [1]

Oxygenation
Plant roots need to be exposed to oxygen as well as moisture, Airlifts can provide both at once [2]

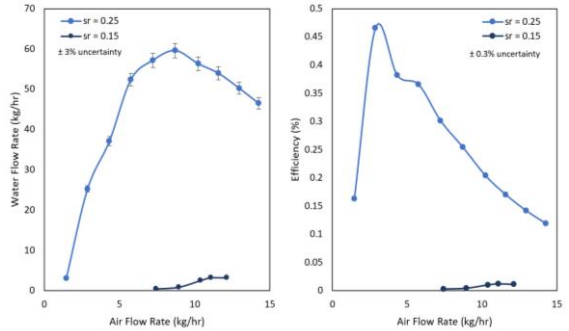
Biofouling
Simplicity and lack of moving components in airlift pumps can reduce the chance of biofouling occurring [4]

Problem Description

Airlift pumps are less effective at low submergence ratios and high heads, therefore, optimizing airlifts for these conditions can provide more advantages in vertical farming applications.

Pulsating Injection Analysis at Low Submergence Ratios

Experiments were taken using a 1-inch FloNergia © airlift pump operating at a 50:50 dual injection mode to collect baseline pump performance and efficiency curves at low submergence ratios (0.25 and 0.15 sr). The air flow rate that produced the highest performance value was determined to be at 8.7 kg/hr. This was then used for the following pulsation testing at the 0.25 sr.

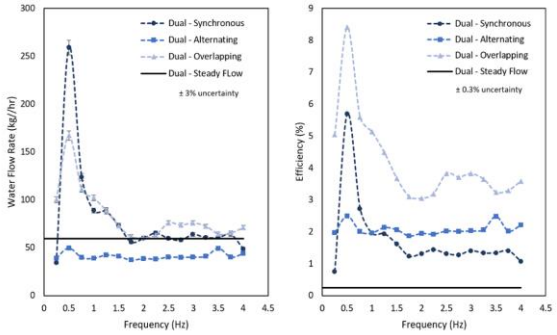


Baseline Continuous Flow Tests

Axial Air Injection
Enhanced water lifting

Radial Air Injection
Enhanced oxygenation

The air injection was then pulsated utilizing solenoid valves to organize two-phase flow bubbles in the riser. Three pulsating injection methods (synchronous, alternating & overlapping) were tested at frequencies between 0 - 4 Hz at 0.25 Hz intervals. Pulsation mode and frequency had a noticeable effect on performance.

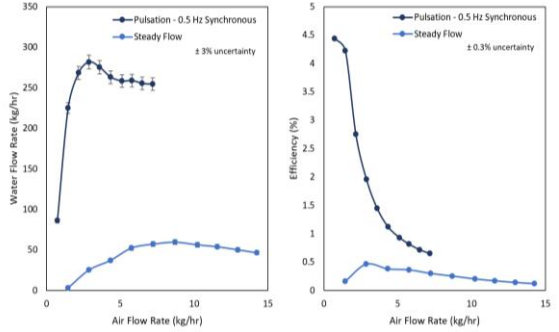


Pulsating Injection Modes Tests

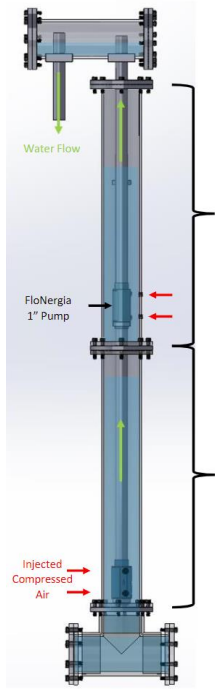
Synchronous and overlapping modes showed improvement compared to continuous flow injection, while the alternating mode diminished the performance overall. The pulsation frequency of 0.5 Hz showed a significant spike in both performance and efficiency. Therefore, a synchronous pulsating injection at 0.5 Hz was used as the optimal setting, as it resulted in the highest water flow rate. All three injection methods showed an increase in efficiency.

Optimal Performance Pulsation Setting Tests

The optimal performance pulsation setting was tested along a range of air flow rates. A clear improvement in performance was seen when the injected air was pulsated. The efficiency was also greatly improved due to half the amount of air being used when the solenoid was opened and closed. There is immense potential for pulsating injection methods as it allows the airlift to operate under low submergences often used in hydroponics.

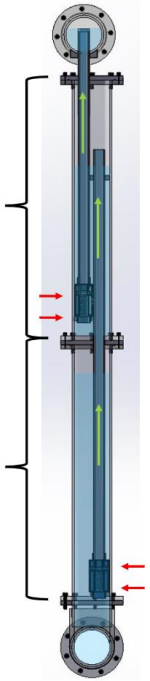


Multi-Stage Airlift Pump Design



Side View

To allow the airlift pump to lift liquids to even higher heads, a new system was conceptualized. The multistage airlift pump utilizes the idea of stacking multiple airlift pump stages on top of one another to achieve a higher lifting height at lower submergences. Each stage contains a 1-inch dual injector FloNergia © pump. The separate stages act as small tanks to contain the required water volume in which the airlift can be submerged in in order to operate. The multistage pump allows for additional stages to be added as needed. Future work can carry out experiments comparing the performance of the multistage airlift pump to a single pump and riser system, implementing pulsating injection modes to further test performance improvement for vertical farming applications.



Front View

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Acknowledgements

Ontario Ministry of Agriculture, Food and Rural Affairs
Ontario Agri-Food Innovation Alliance
FLOWERGIA