Comparing Pressurized Micro-bubble Generation to Traditional Air Stone Aeration

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Abstract:

This experiment seeks to test microbubble aeration ~~(pressurized air)~~ versus traditional air stone ~~(non-pressurized air)~~ aeration. Aeration occurs every other day on nutrient reservoirs used to grow lettuce, our dependent variable, in a drain-to-waste system. Microbubble, while best producer, did not perform to hypothesized level of success. In addition the control outperformed the air stone, indicating subsequent research and a change of the experiment is necessary.

Introduction:

A microbubble generator was used to ~~pressurize air into~~ produce dense micro bubbles ~~averaging 50~~ of 30-50 microns across in size. ~~This small size allows the internal pressure to balance with surface tension of~~This allows the bubbles ~~allowing them~~ to stay suspended in solution longer allowing full dissolution of ~~oxygen~~ air into water. This is to achieve ~~b~~oth more efficient aeration and to allow the solution to then become ~~super~~saturated ~~to higher~~ dissolved oxygen more efficiently than is ordinarily achieved with traditional aeration. Air stones can create bubbles over 1000 microns ~~wide~~ that then bubble to the surface where most ~~oxygen~~air is subsequently lost back to the atmosphere. This experiment's purpose is to determine if this difference in size of the air bubble produces a measurable difference on lettuce growth and other growth factors (dissolved oxygen, pH, microbes) when applied to reservoir water.

Materials and Methods:

In this experiment four 12-gallon reservoirs were used, each aerated with a different method, with the final reservoir acting as a control with no aeration at all. A microbubble generator using an accumulation tank and pump producing ~~50-L/Hr~~ 30L/Hr air was for one reservoir. For the other reservoir, an air stone hooked up to a pump capable of producing a comparable 45-L/Hr air was used. Aeration was done for 5 minutes each time with both dissolved oxygen readings and plant feeding being taken immediately following this time. Fresh solution was created approximately every two weeks, with feedings occurring every two days. Each lettuce plant was fed 500-ml of solution.

The water used was put under 3-stage water purification; 5 micron pre-filter, activated carbon, and reverse osmosis to a final TDS of < 50 ppm. The nutrient line used was General Hydroponics Micro, Cal-Mag, and Veg. Due to the wide pH tolerance of lettuce, the pH was often left unchanged and averaged 5.8-6.2 with an average ppm of 600-900 for freshly made solution.

Ten lettuce heads were grown for each aeration technique, each for approximately 35 days following transplant. Three trials of the experiment were performed with wet weights measured at time of harvest, and a food dehydrator was used to measure dry weight.

Manual and automated sensors were used to measure various dry and wet variables relating to plant growth. All automated Sensors were run by Arduino Yun microprocessors which relayed the measured data to a mySQL database. The dry variables measured were air temperature, humidity, and light. A DHT22 temperature & humidity sensor, and a BH1750 light sensor were combined to create 4 dry sensor modules. Dry-sensor modules were installed inside 1 growth chamber of each aeration type to monitor data for the first 2 trials. One dry-sensor module was used in the center of the greenhouse for the third trial after it was concluded that differences between growing chambers were negligible. The wet variables measured in each of the 4 water reservoirs were pH, Electrical conductivity, Dissolved Oxygen, and temperature. Atlas Scientific EZO pH, EZO DO, & EZO EC sensors were combined with a DS18B20 waterproof temperature sensor to create wet-sensor modules which were installed in each of the 4 aeration reservoirs. Due to systemic bugs with the automated wet-sensor modules, manual sensors were also used to supplement the automated data and ensure its validity. For manual data collection, a BlueLab pH Meter was used to measure pH, a Hanna HI98129 sensor was used to measure to EC, a YSI DO200A Dissolved Oxygen Meter with Temperature Compensation sensor was used to measure DO, and a standard mercury thermometer was used to verify temperature readings.

Results

After measuring wet and dry weight of the final product, it was found that micro-bubble out-produced the airstone and control.

Final Lettuce Wet/Dry Weight (grams)			
Wet/Dry Weight	MicroBubble	Air Stone	Control
Trial 1 (average)	289/16.2	269/12.8	268/14.1
Trial 2 (average)	169/12.9	128/9.4	158/11.9
Trial 3 (average)	233/13.3	221/10.5	227/12.0
Total Average	231/13.3	206/10.5	218/12.0
% Weight Retained Wet □ Dry	5.78	5.11	5.50

Fig 1: Table showing final lettuce weight average for all trials (wet/dry)

Air temperature, humidity, light, and EC of the reservoir went unchanged from beginning to end of the experiment.

Average	Dissolved Oxygen	pH	EC	Water Temperature
Microbubble	9.6	6.0	700	18°C
Air Stone	9.6	6.0	700	16°C
Control	5.6	6.1	700	16°C

Fig 2: Average manual readings for dissolved oxygen, pH, and EC

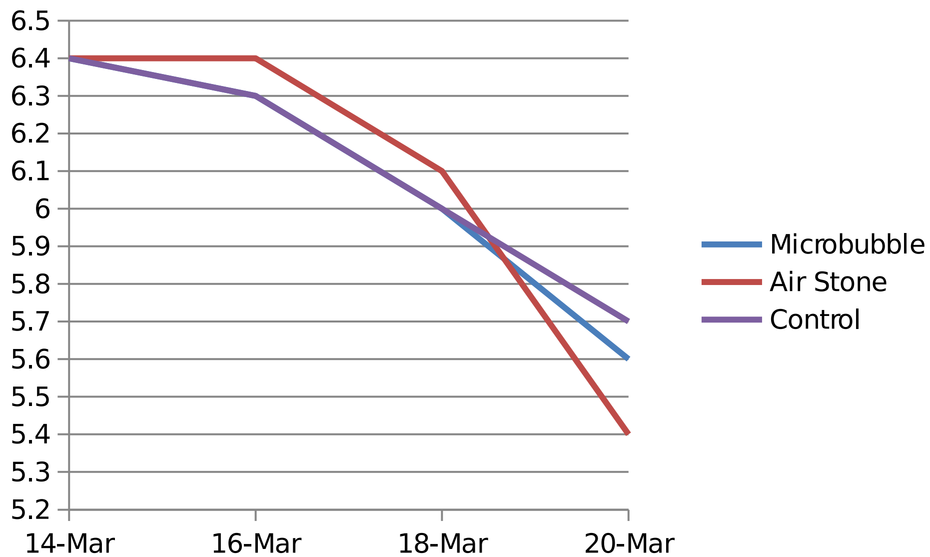

Fig 3: pH readings from beginning of reservoir change to end

Conclusions

Lettuce leaf number, lettuce diameter, and dry weight all ultimately correlated directly to the wet weight making wet weight the best metric for determining lettuce health and success between different experimental variables.

While final data did indicate microbubble to be the advantageous form of aeration, it was not as effective and dominant as expected. Control and micro-bubble were consistently the top producers, despite a difference in dissolved oxygen, indicated that lettuce itself is not affected by dissolved oxygen concentrations as confirmed by Albright LD 1996 (1)

Most CO_2 sensors followed correct atmospheric trend, but lacked accuracy to adequately distinguish from one-another, more accurate CO_2 sensors needed. Humidity, Light, CO_2, Water

Temp, and Air Temp are not believed to have significant enough of differences to affect the results.

Optimal pH in Coco Coir Substrate used is pH 5.9, while lettuce has an optimal pH range of 6.0 to 6.5. Rises in water pH is often the result of microbial activity, while decreases in pH indicates decomposing organic matter (decaying microbials) The combination of sitting stagnant with occasional aeration seems to of stimulated bacteria causing an increase in pH resulting in more organic material, followed by a die-off causing a decrease the pH.

It is believed the initial increase in pH observed was because at certain times the anaerobic bacteria would grow causing an increase in pH (consume peptides and produce ammonia as a bi-product and increasing pH), when being aerated the bacteria would die-off resulting in decaying organic matter which decreases pH. Aeration and de-gassing would also allow atmospheric carbon dioxide to dissolve to form carbonic acid, which then decreases the pH. PH changes in the micro-bubble were the smallest compared to the other reservoirs, this is believed to be a result of the anti-microbial properties of micro-bubble, as explained by Sharma PK 2005 (2) and Shozo Himura 2009 (3). When micro-bubbles are formed, they are created under pressure giving them an electrical charge on the outside. When coming into contact with water, they contract followed by an expansion, producing a spherical shockwave that also creates free radicals. The free radical is produced via the attached charge, which also attracts organic contaminants/bacteria. The combined mechanical shear of the de-pressurization shockwave, and the biochemical oxidation by the free radical oxygen molecules created, inactivates/kills the bacteria. (4)

The resulting lack of bacteria and organic matter build-up led to the micro-bubble to incur the smallest pH change of any of the reservoirs. Qualitative proof of this came in the level of bio-film seen on the inside of the reservoir and tubing in the reservoirs (fig 4), where micro-bubble had the least amount. It is believed that the lack of gas-exchange in the control reservoir prevented atmospheric carbon dioxide from being allowed to form into carbonic acid when compared to the constant air-stone, whose constant de-gassing would push the equilibrium of the reaction towards favoring additional carbonic acid formation. The low pH then had a downstream effect of making the water a non-ideal pH for the lettuce growth. It is believed that pH was the largest factor influencing lettuce yield, and while all other sensors indicate fairly homogenous conditions, pH fluctuated the least for the control and micro bubble.

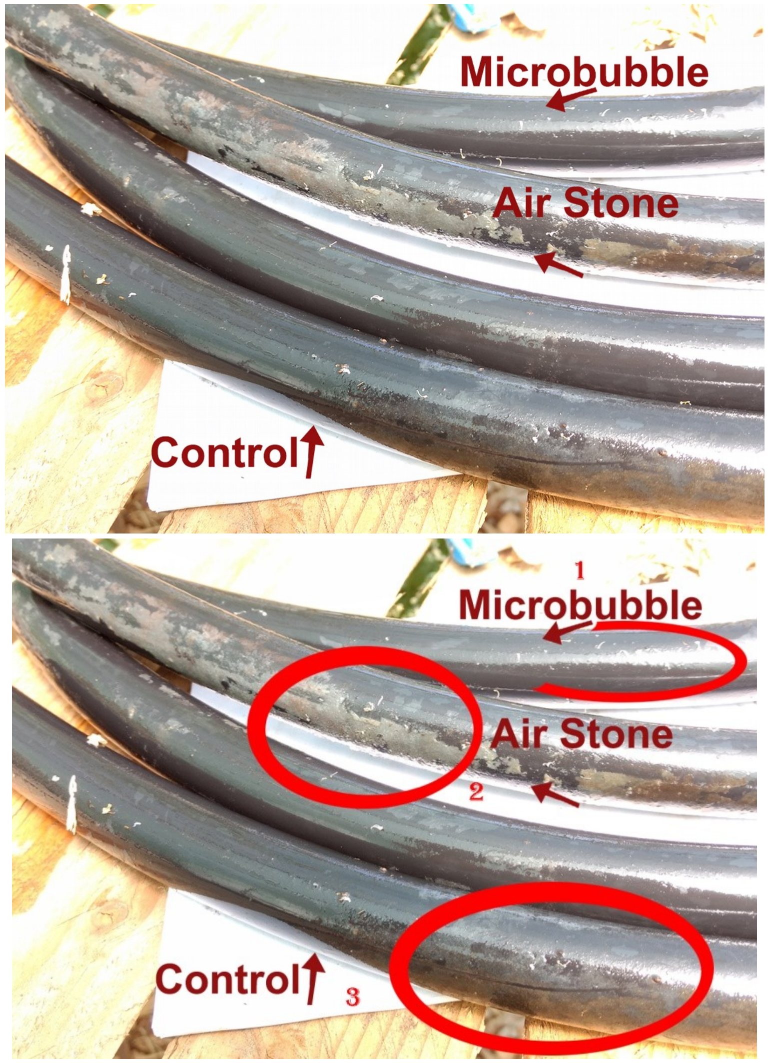

Fig 4: Best photo evidence to describe observed differences of biofilm on reservoir-fill lines for different aeration types. 1: Microbubble biofilm so nonexistent it creates glare for the camera
2: Air Stone biofilm was thick and caused the tube to become slimy and brown
3: Control biofilm was moderate with only sections covered in a light layer of biofilm.
~~Fig 4: Observation of biofilm on reservoir-fill lines for different aeration types~~

No change was observed in EC/TDS indicating no ammonia or nitrates were de-gassed from the solution, nor extensively consumed by any bacteria. While there is evidence of microbial activity in the reservoirs, it is not significant enough to affect the available nutrient levels or EC. Poor sensor data for EC is believed to be a result of incorrect sensor type (designed to read higher EC readings than what we are using). Manual readings of the EC with the Bluelab probe are believed to be sufficient. EC run-off is highest for the poorest performing plants, indicating healthier and more productive plants drew more nutrients from the medium, and thus did not correlate to aeration type.

Most data collected from the sensors was unfortunately unusable due to the need of electrical isolation from the probes. Anytime the microbubble pump was turned on it would produce an unwanted current that would interfere with the sensors. For future experiments individual sensors would need to be equipped with an electrical isolator in order to maintain clear, accurate readings during aeration. To avoid this, sensors were switched off during aeration later in the experiment, however, pin-point readings were difficult to read.

It is believed that if a future experiment were to be performed, carbonate (KH) levels should be tested between the reservoirs to determine carbon dioxide gas exchange. In addition, due to the lettuce plant's indifference towards dissolved oxygen levels, a different crop should be selected. The biggest adjustment to better test the properties of the micro-bubble generator, when compared against an air stone or absence of aeration, would be to create a hydroponic system (ebb-flow/bubbleponics/or deep water culture) as opposed to the drain-to-waste system utilized for this experiment. This way, you can also see if there is any effect from small air bubbles to be attached to the roots of plants.

Acknowledgements

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