

One Step Closer to Mars with Aquaponics

A novel approach to sustainable agriculture.

Introduction

2016-17

Science Fair

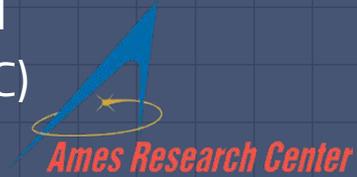
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Extensions



Acknowledgements

Angela Detweiler and Brad Bebout (NASA Ames) both performed and analyzed the MinION sequencing runs, with the help of Mike Lee (USC) Miten Jain and Hugh Olsen (UCSC)



Funding for this project came from a NASA Scientific Innovation Fund Grant "Biology IS the technology" during FY 17 and Donors Choose with a Tom's of Maine match grant, as well as a grant from the Aquaponics Association



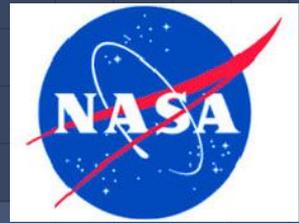
Meadow Park Students of 2016-2017 and SST students of 2017-2018



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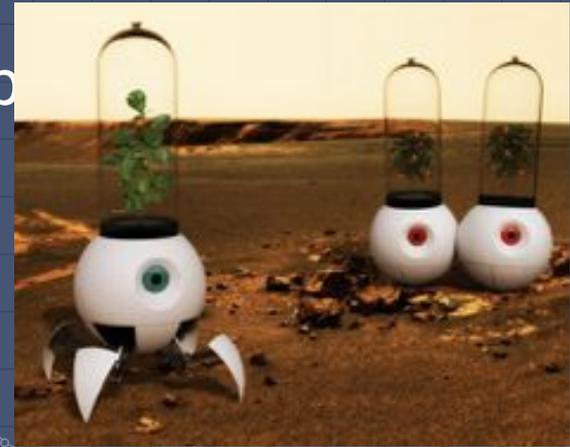
Introduction





Why does NASA care?

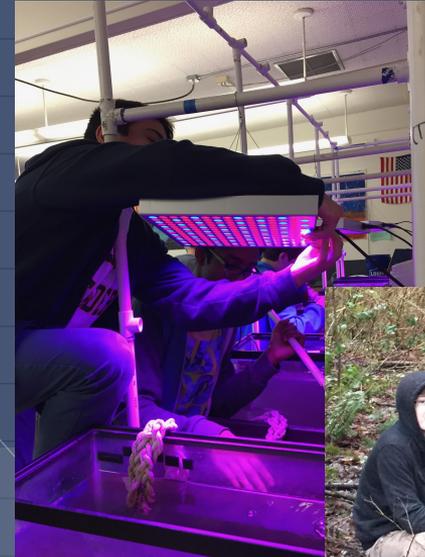
- Food production is key to long term space travel
- Aquaponics can serve as a model for what could be used for long term space travel
- To develop the most efficient/most plant based system
- Large scale citizen science



Introduction

Science in a Classroom Setting

- Over 55 middle school students
- More possible replication than in most labs in the same time frame
- Faster, and great data
- Citizen Science in our schools
- Follows Curriculum for students
- Unique Experience and Exposure for Students



Introduction

Aquaponics 1.0

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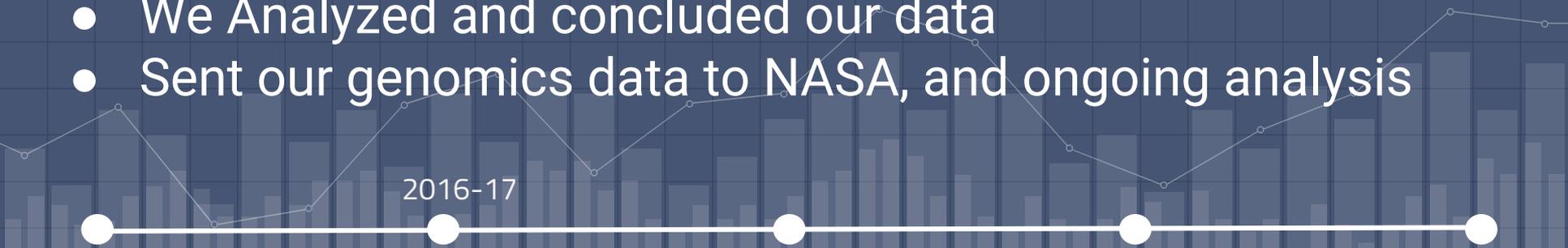
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Extensions

From the ground up, we engineered, maintained and analyzed 10 aquaponics systems.

- We engineered 10 different small scale aquaponic system
- We received funding from NASA, and funded the rest on our own
- Each system experimented with different variables
- We performed daily tasks
- We Analyzed and concluded our data
- Sent our genomics data to NASA, and ongoing analysis



2016-17



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Research Question

How do we create the most efficient aquaponics system with microbes that promote stable plant and fish growth with steady nutrient cycles?



Variables and Hypothesis

- Compared plant growth rate to many other variables
- IV: Plants, lighting, water circulation,
- DV: Plant growth (height, leaves)
- Constants: fish and water.
- Hypothesis: The addition of the EM-1 inoculant will lead to an increase in plant growth due to plant growth promoting bacteria.



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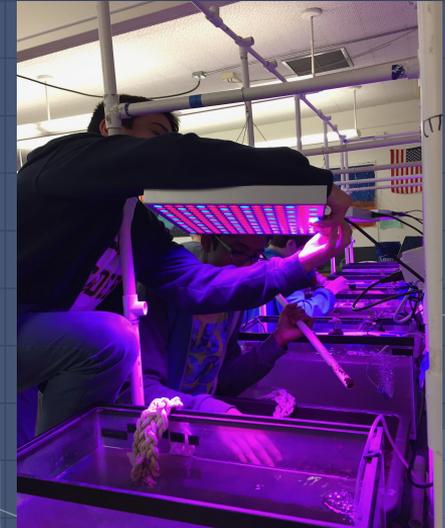
Original Experimental Setup

Three major structures:

- 10 gallon fish tank
 - Fancy and Comet Goldfish
 - Positive control plant group
- Plant bed
 - Experimental Plant Group
 - Media (three treatments)

- Light

- PVC pipe structure



2016-17

Original Experimental Procedure

- Floating bed construction
- Masking tape
- Basil, Tomatoes, Peas
- Daily: Nitrate, Nitrite, Ammonia, pH measurements, conditioning changes



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NASA used a MinION Sequencer to find genus

- Sent NASA water samples from tanks. 10 tanks and 3 time points
- Performed PCR in preparation for MinION



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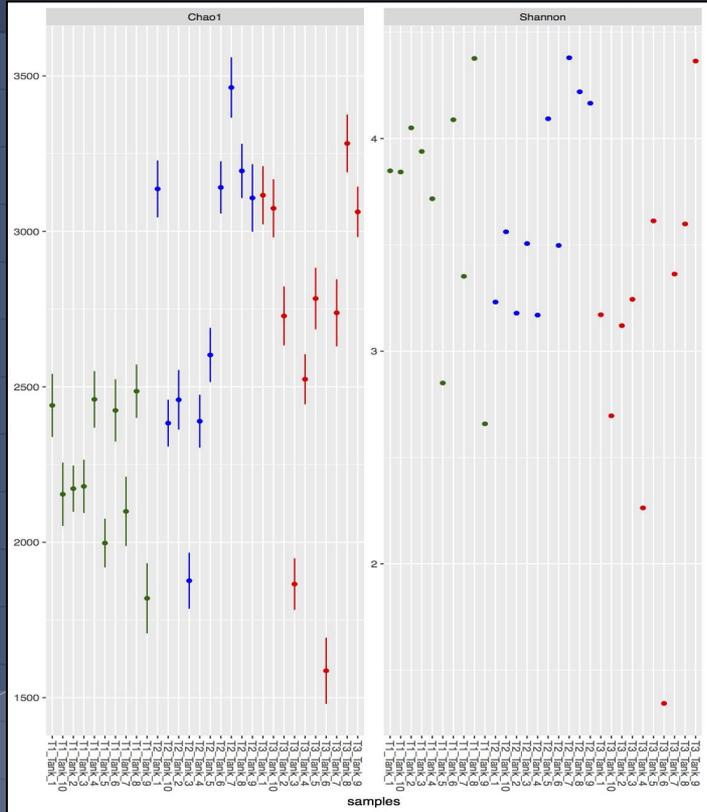


Used R to processes large amounts of data

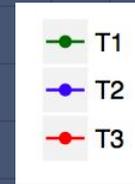
The screenshot displays the RStudio interface with the following components:

- Script Editor:** Contains R code for calculating alpha diversity. The code includes comments and function calls like `rarecurve` and `abline` to generate a plot. A warning message is visible in the console: "Warning message: In rep(col, length.out = nr) : 'x' is NULL so the result will be NULL".
- Environment:** Lists objects in the global environment, including `taxonomy_tab` (6192 obs. of 7 variables), `temp_filtered_m` (9 obs. of 32 variables), `unclassified_pr` (num[0, 1:32]), `class_counts_tab` (Formal class otu_table), `counts_phy` (Large otu_table (198144 elements, 1.8 Mb)), `filtered_propor` (Named num [1:32] 1.56 0.65 2.2 0.7 0.89 ...), `proteo_classes` (chr [1:8] "Acidithiobacillia" "Alphaproteoba..."), `tax_phy` (Large taxonomyTable (43344 elements, 1.4 Mb)), and `unclassified_co` (Named num [1:32] 11088 20555 11597 24351 457...).
- Console:** Shows the execution of the R code, including the error message: "Error in DESeqDataSetFromMatrix(otu_counts_tab, colData = sample_info_tab, : could not find function 'DESeqDataSetFromMatrix'" and the warning message mentioned above.
- Plots:** A plot titled "OTUs" vs "Sample Size" is displayed. The x-axis ranges from 0 to 250,000, and the y-axis ranges from 0 to 2,000. Multiple colored curves represent different tanks, with labels such as "T1 Tank 1", "T2 Tank 1", "T3 Tank 1", etc., indicating the sample size at which each tank's curve was plotted.

Data Analysis: Microbe Diversity



Biodiversity across at the family level using Shannon and Chao1



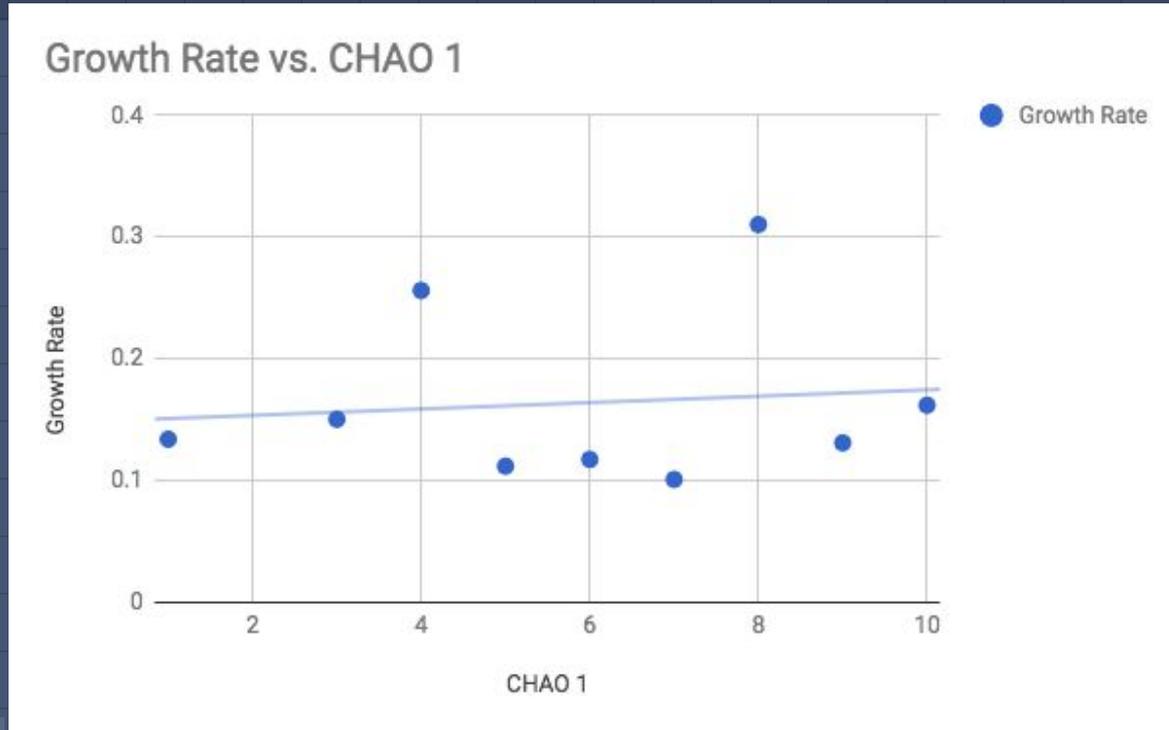
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Data Analysis: Plant Growth

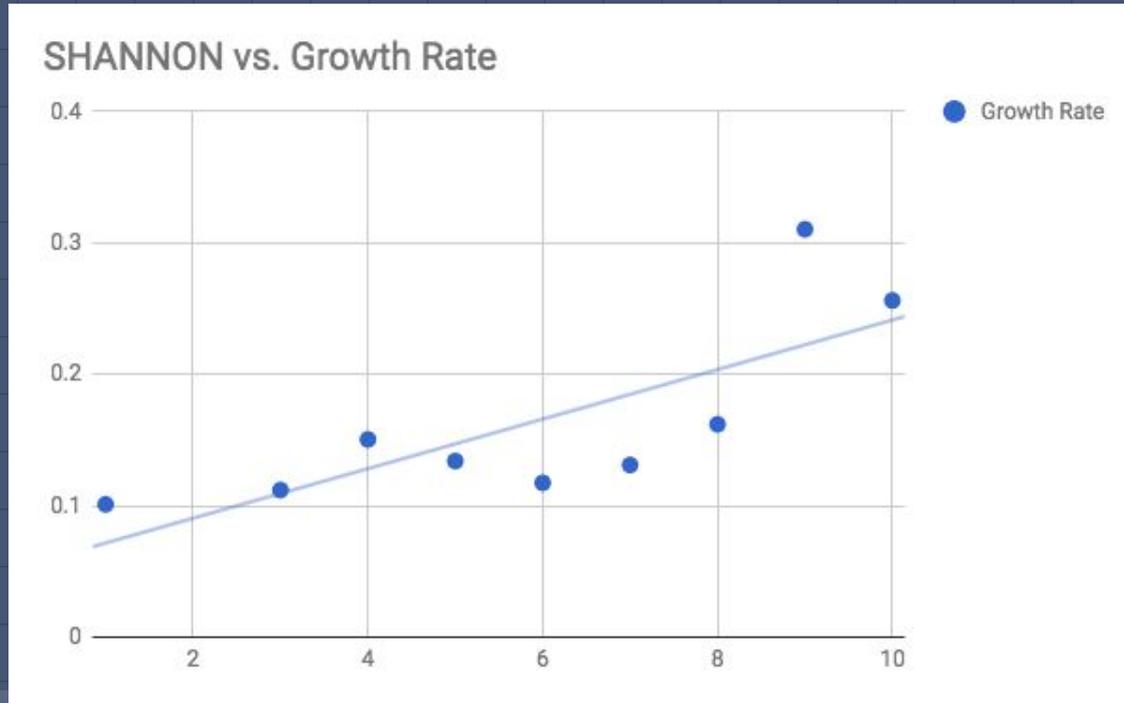
The following graphs exclude one tank because it was an extreme outlier that was skewing the data.



There is a slight positive correlation between growth rate and Chao 1 index values.



There is a positive correlation between growth rate and Shannon index values.



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Conclusions and Future Extensions

- What have we learned from this experiment?
- What will we learn in future experiments?

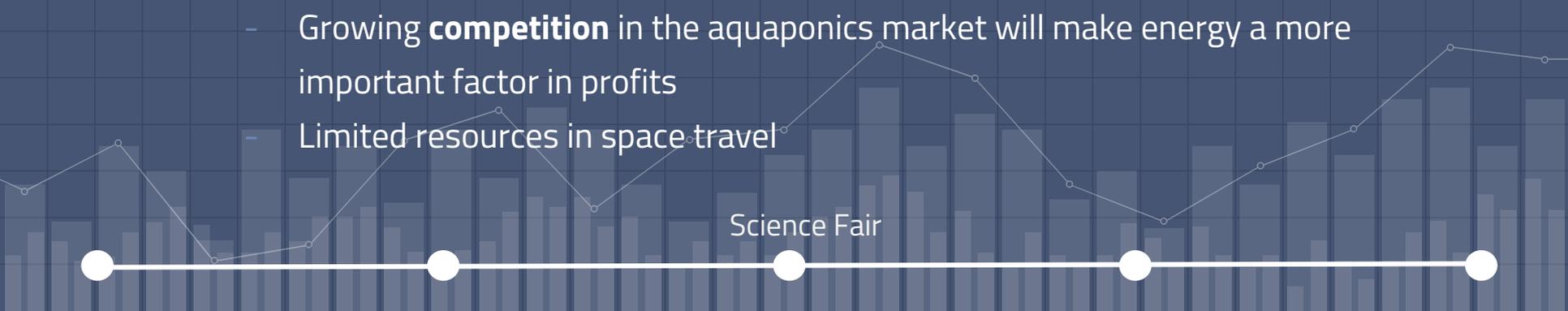


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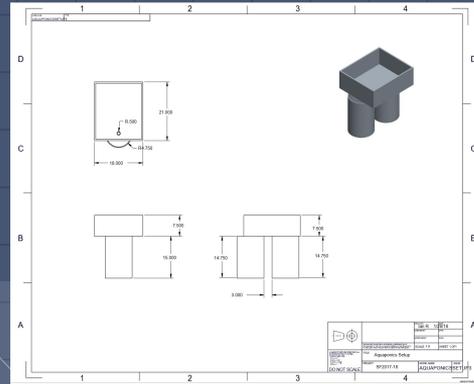
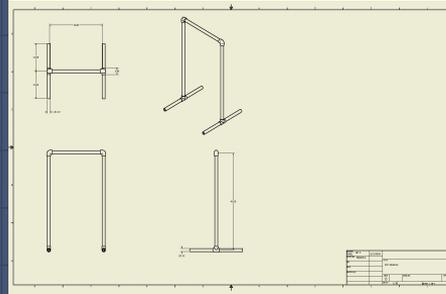
Science Fair: Optimizing Efficiency

- Each system has energy inputs and outputs
 - **Inputs:** Light, Nutrients, Water Cycling
 - **Outputs:** Fish and plant matter
- How to maximize system efficiency?
- Why is this an imminently needed question?
 - Growing **competition** in the aquaponics market will make energy a more important factor in profits
 - Limited resources in space travel

Science Fair

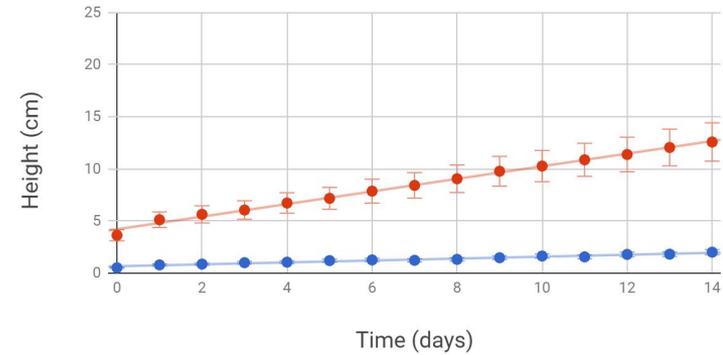


Setup: Building Hydroponic Systems, Analyzing Data



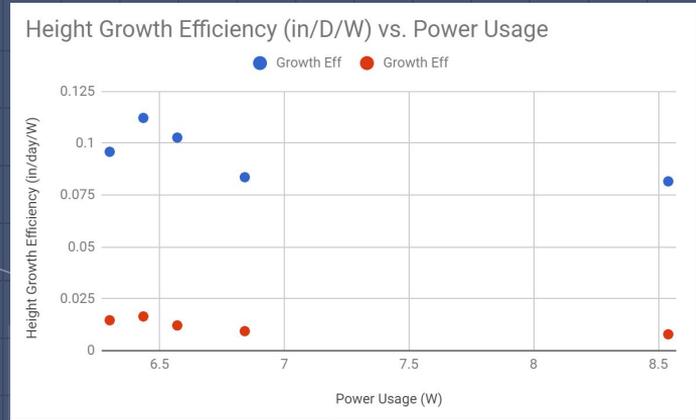
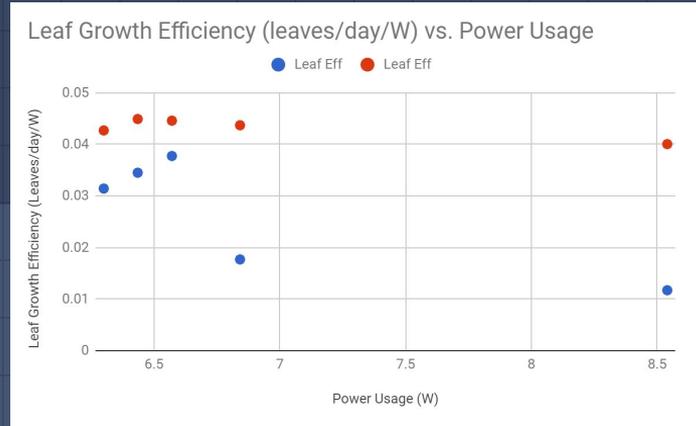
Wick Systems Plant Height (cm) vs. Time (days)

● Basil Avg ■ $0.0922x + 0.658$ $R^2 = 0.971$ ● Radish Avg ■ $0.604x + 4.21$ $R^2 = 0.995$



Data showed an efficiency peak

<i>System</i>	<i>Wavelength (nm)</i>
WICK	428.6
S2	422.8
S1	427.4
S3	428.9
S4	431.3



Science Fair

Conclusions and Future Extensions

- Extensions

- Collecting more data to increase confidence in the notion that there's a peak
- Growth yield vs. amount of wicking material

- Conclusion

- A peak efficiency can be reached in aquaponic systems, but must be pinpointed through experimentation.



Science Fair

Aquaponics 2.0

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Extensions

What changed?

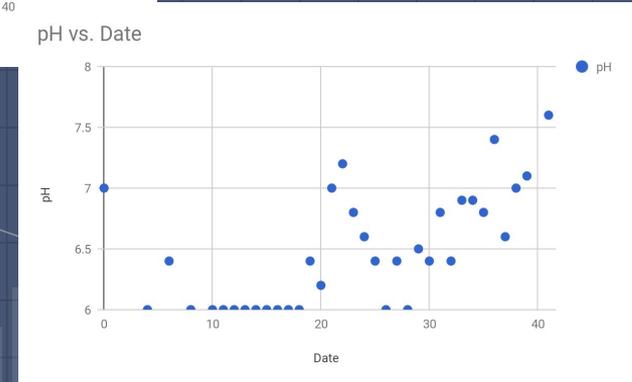
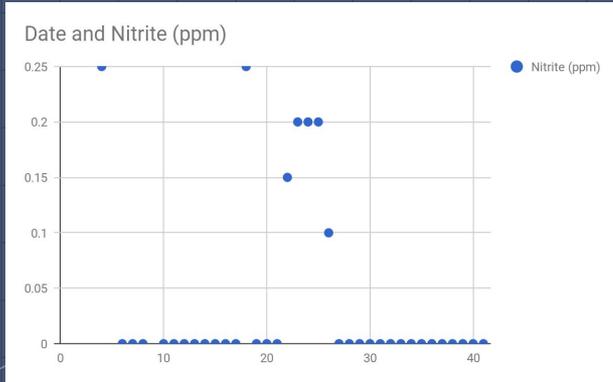
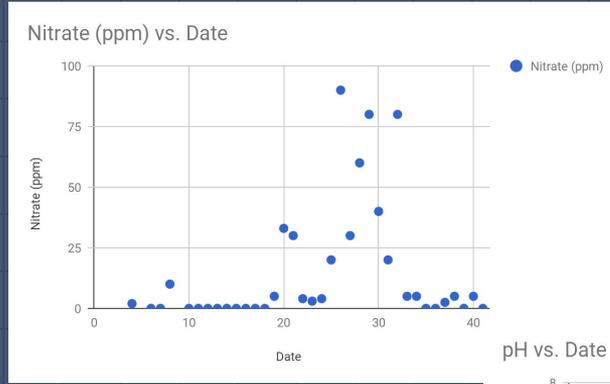
This year's system:

- EM1 (plant growth promoting bacteria) vs no EM1



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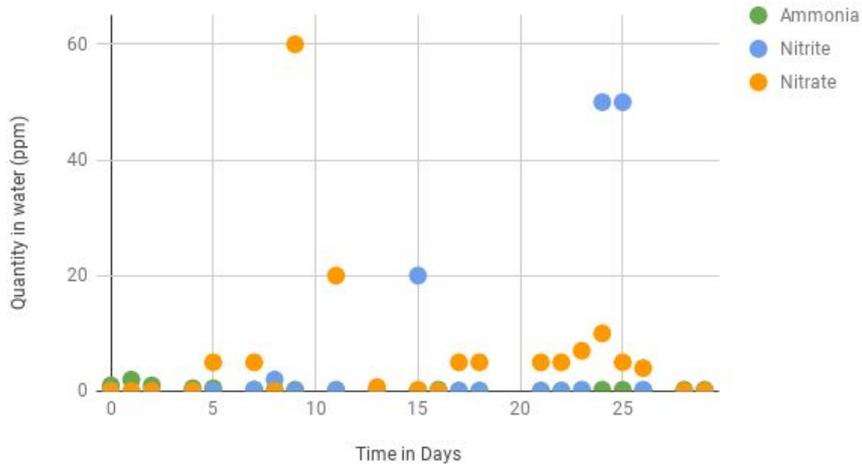
Results: Tank 1: Ammonia, Nitrate, Nitrite, pH



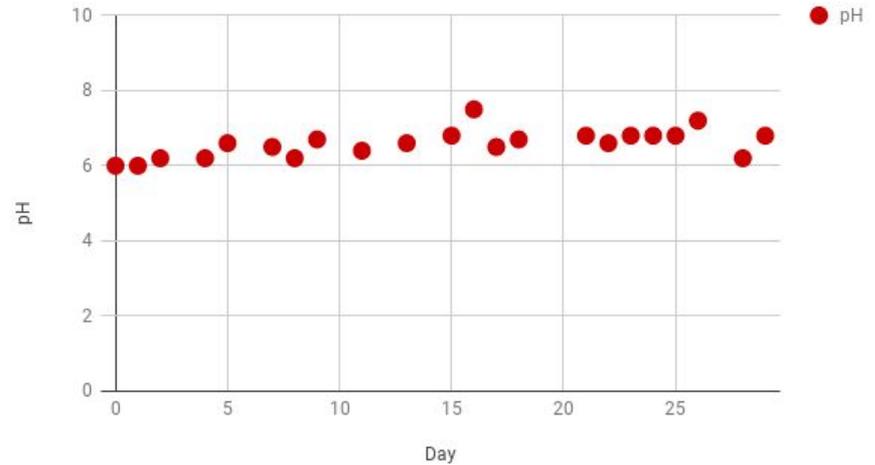
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Results: Tank 2: Ammonia, Nitrite, Nitrate, pH

Tank #2: Ammonia, Nitrite, Nitrate (ppm) vs Day

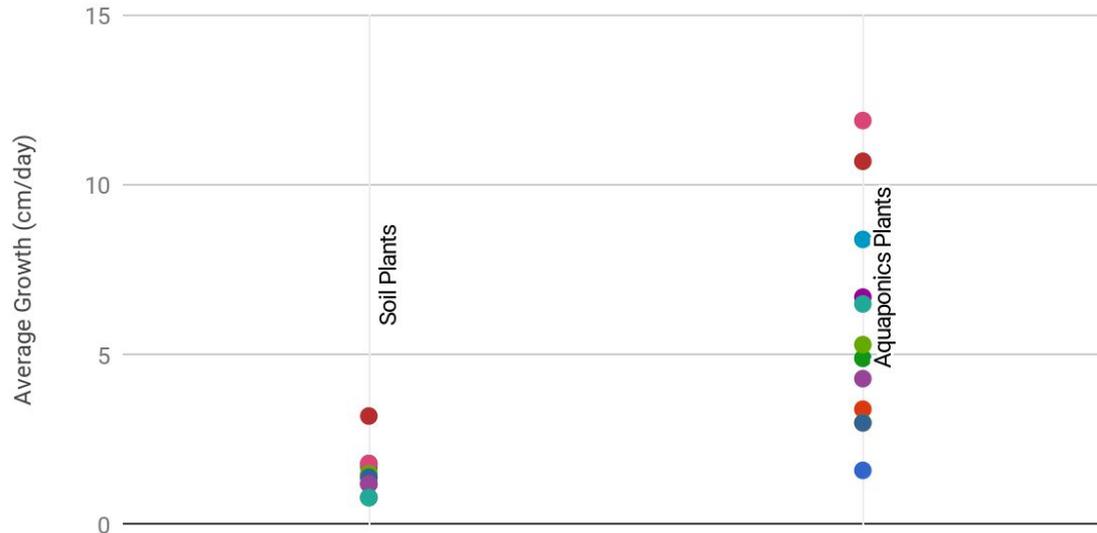


Tank #2: pH Level vs. Day



Results: Tank 2: Plant Growth Avg.

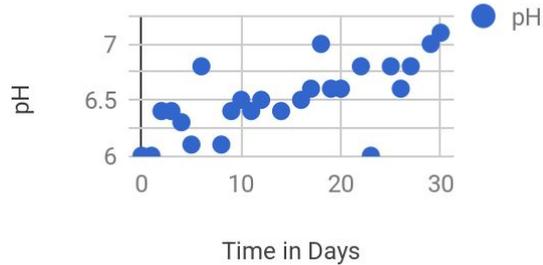
Tank 2: Soil Plants Avg. Growth and Aquaponics Plants Avg. Plant Growth



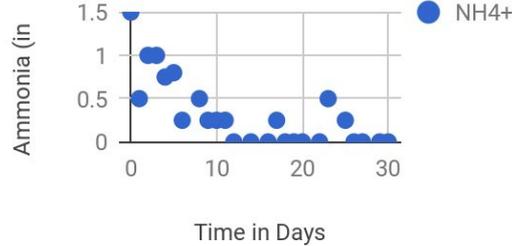
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Results: Tank 3: Ammonia, Nitrate, Nitrite, pH

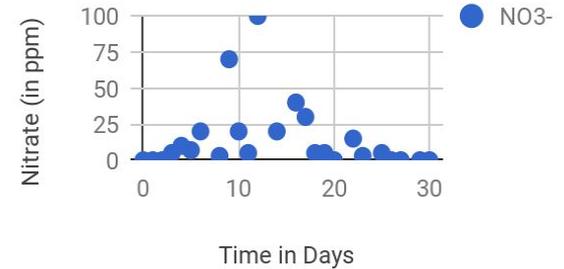
Tank 3 pH Overtime



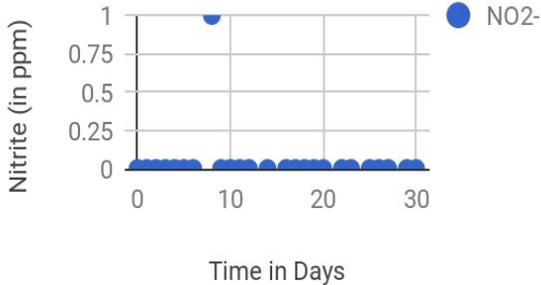
Tank 3 Ammonia Overtime



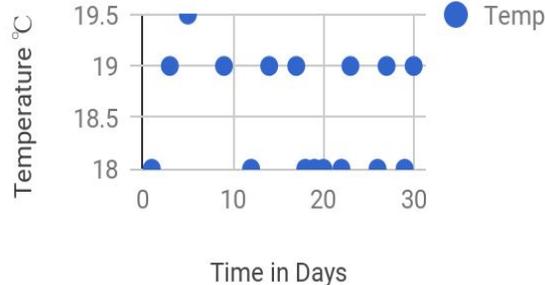
Tank 3 Nitrate Overtime



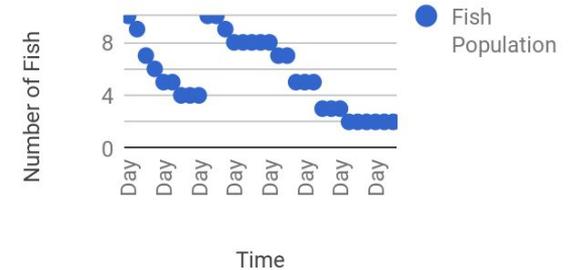
Tank 3 Nitrite Overtime



Tank 3 Temperature Overtime

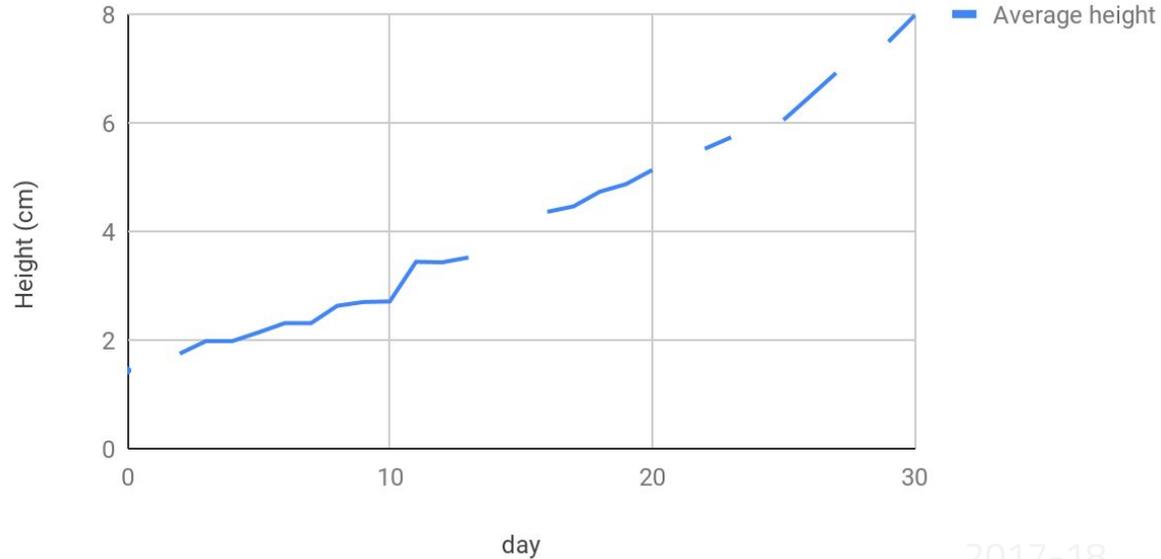


Tank 3 Fish Population



Results: Tank 3: Plant Growth Avg.

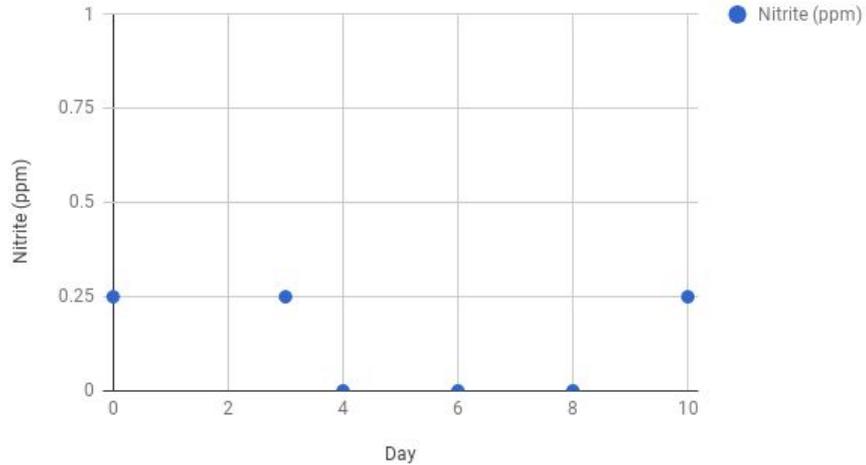
time, height Plant 1, height Plant 2, height plant 3, height plant 3...



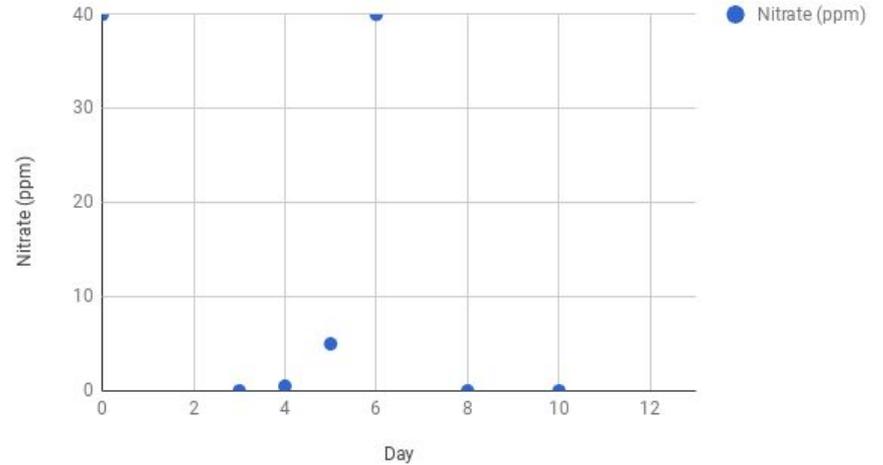
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Results: Tank 4: Nitrate and Nitrite

Nitrite (ppm) vs. Day



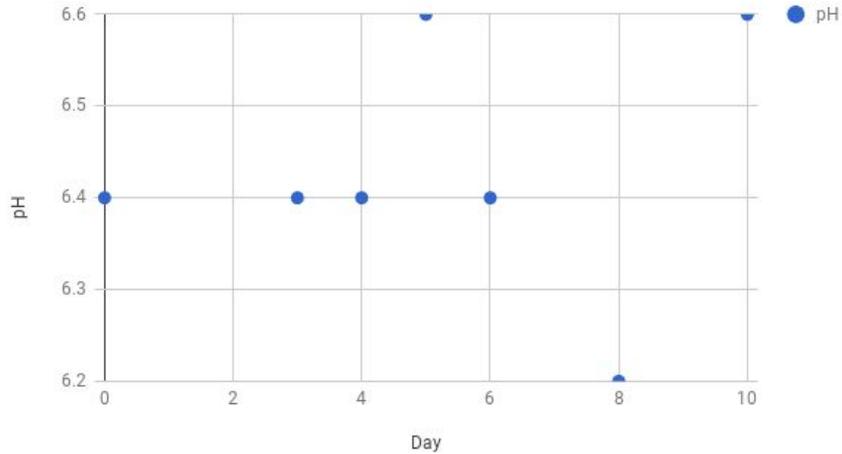
Nitrate (ppm) vs. Day



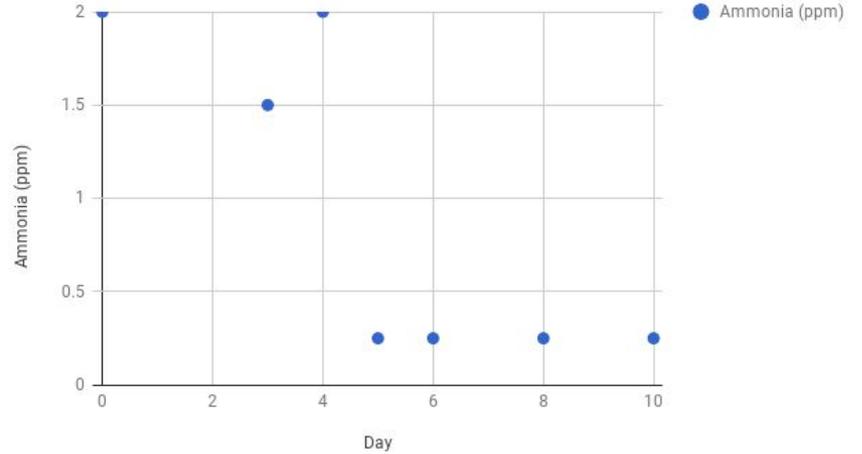
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Results: Tank 4: Ammonia and pH

pH vs. Day



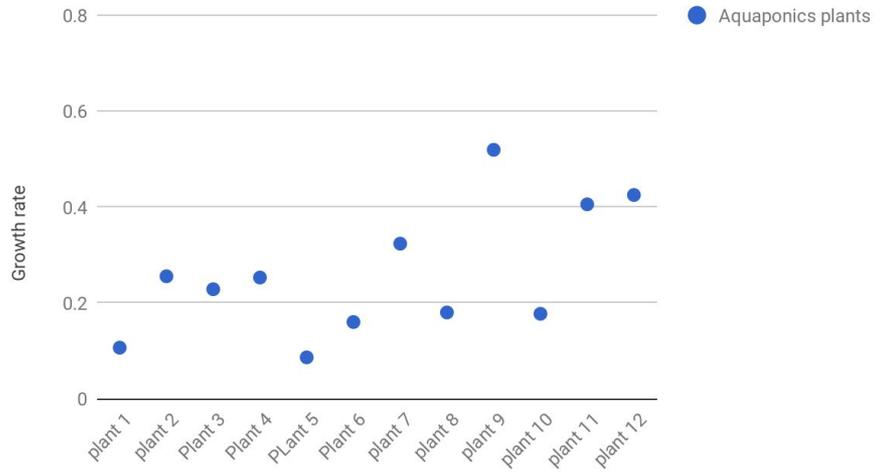
Ammonia (ppm) vs. Day



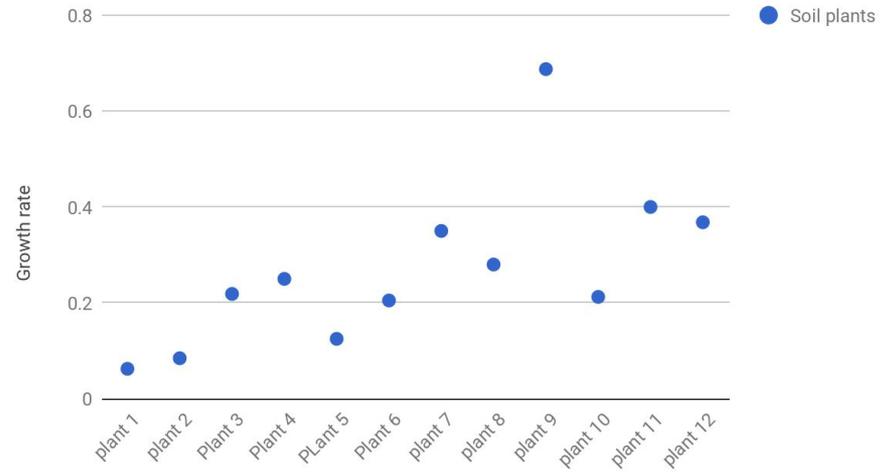
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Results: Tank 4: Plant Growth Avg.

Aquaponics plants

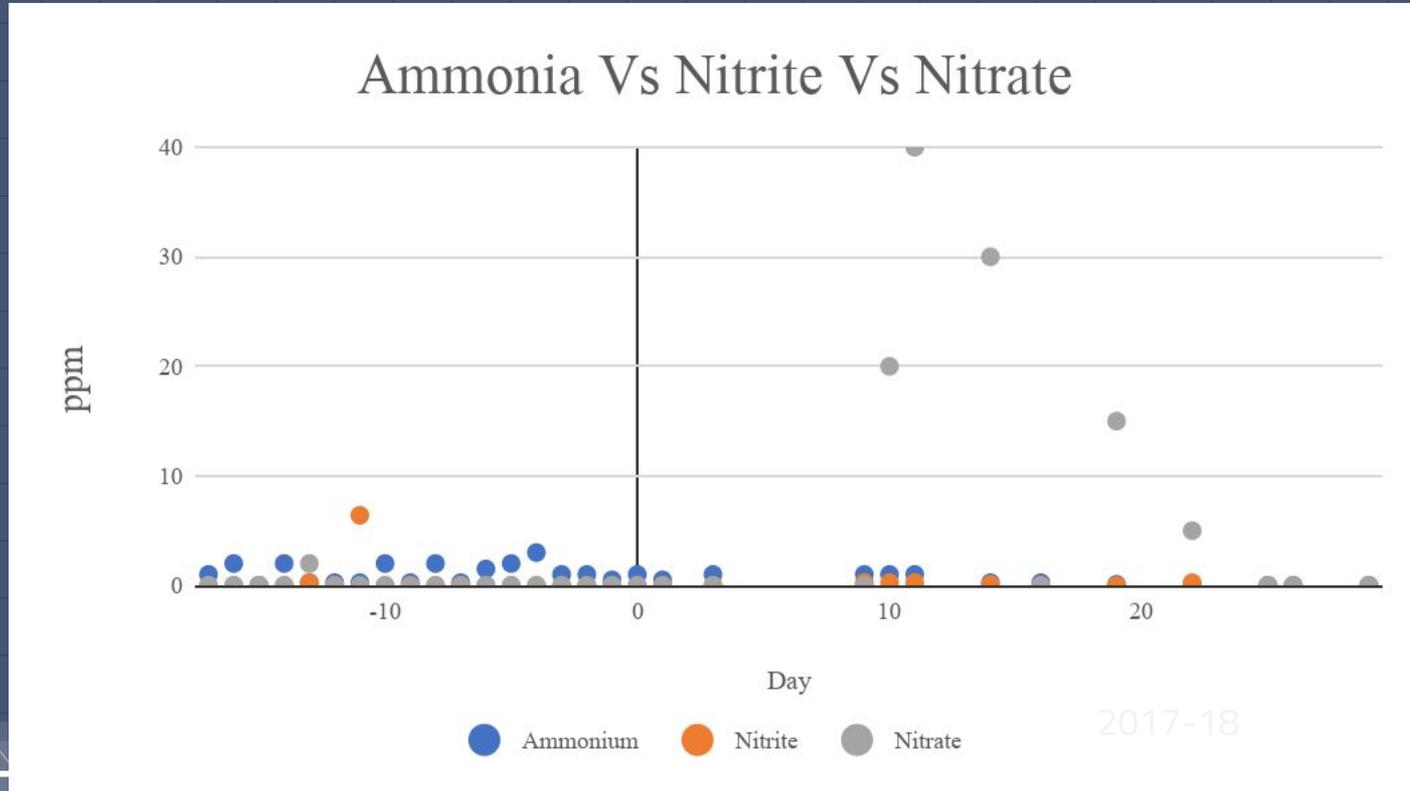


Soil plants

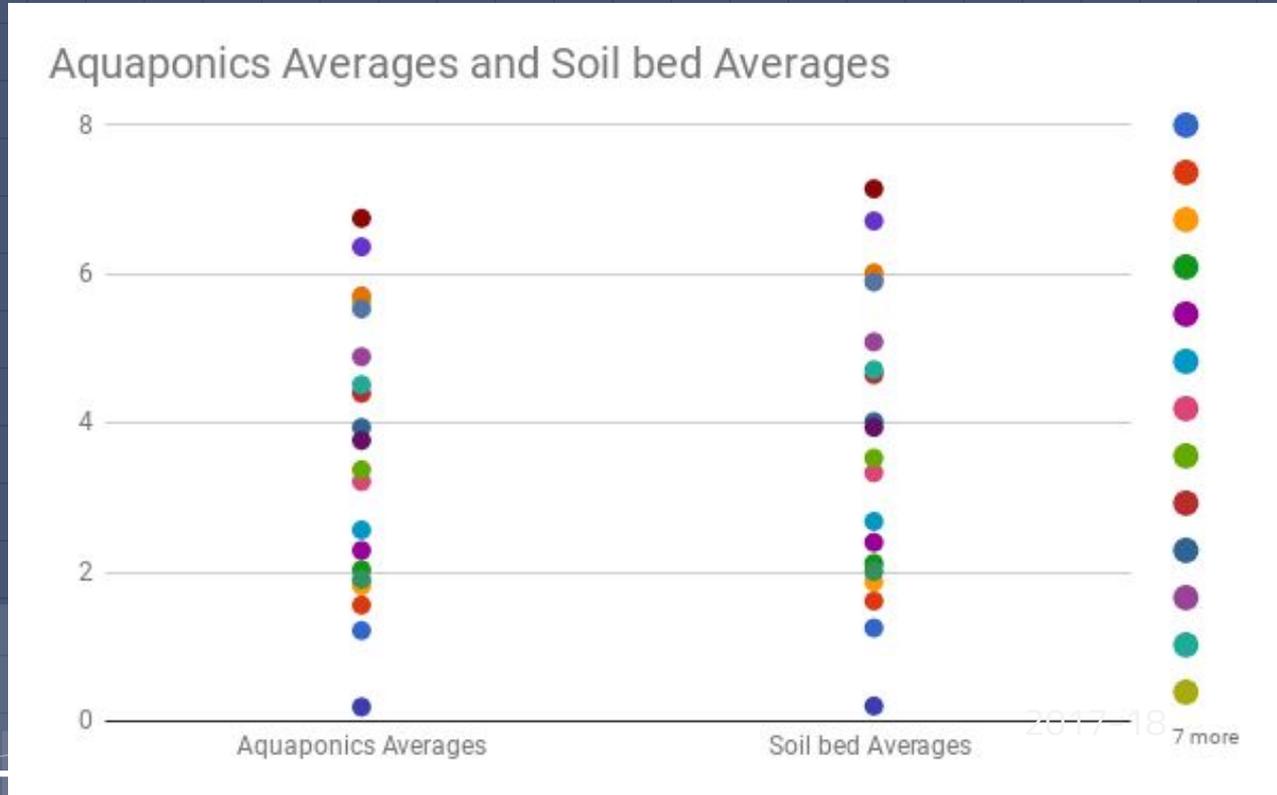


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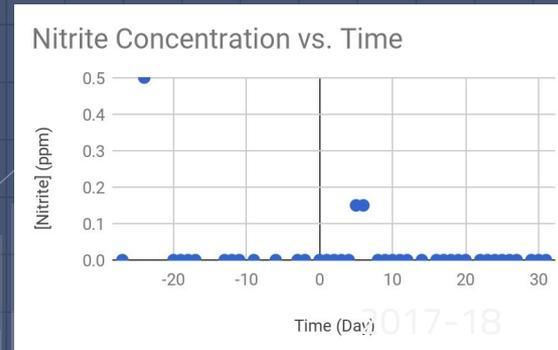
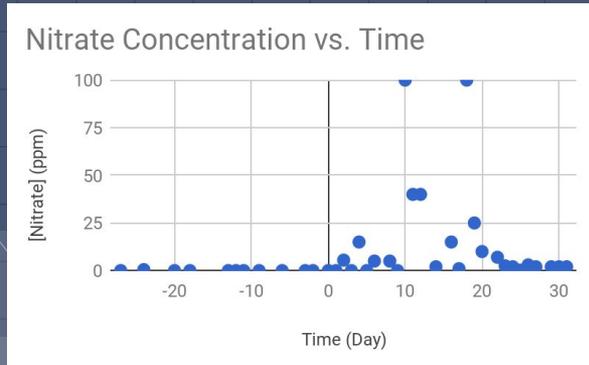
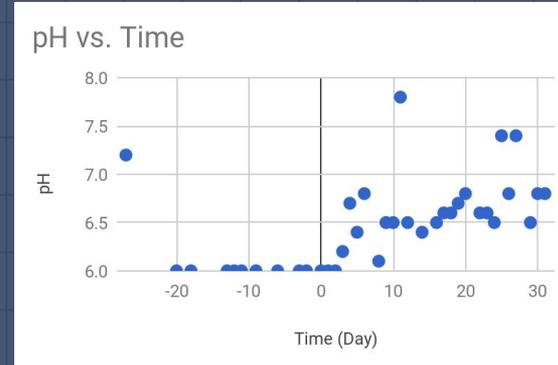
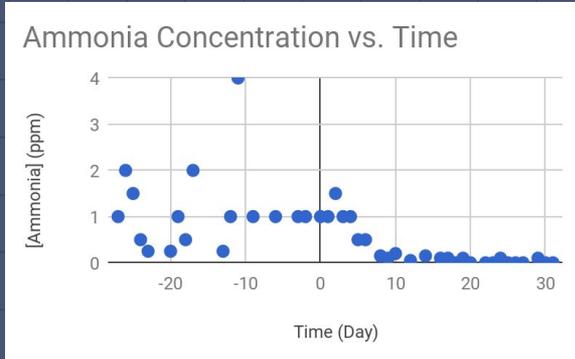
Results: Tank 5: Ammonia, Nitrite, Nitrate



Results: Tank 5: Plant Growth Avg.

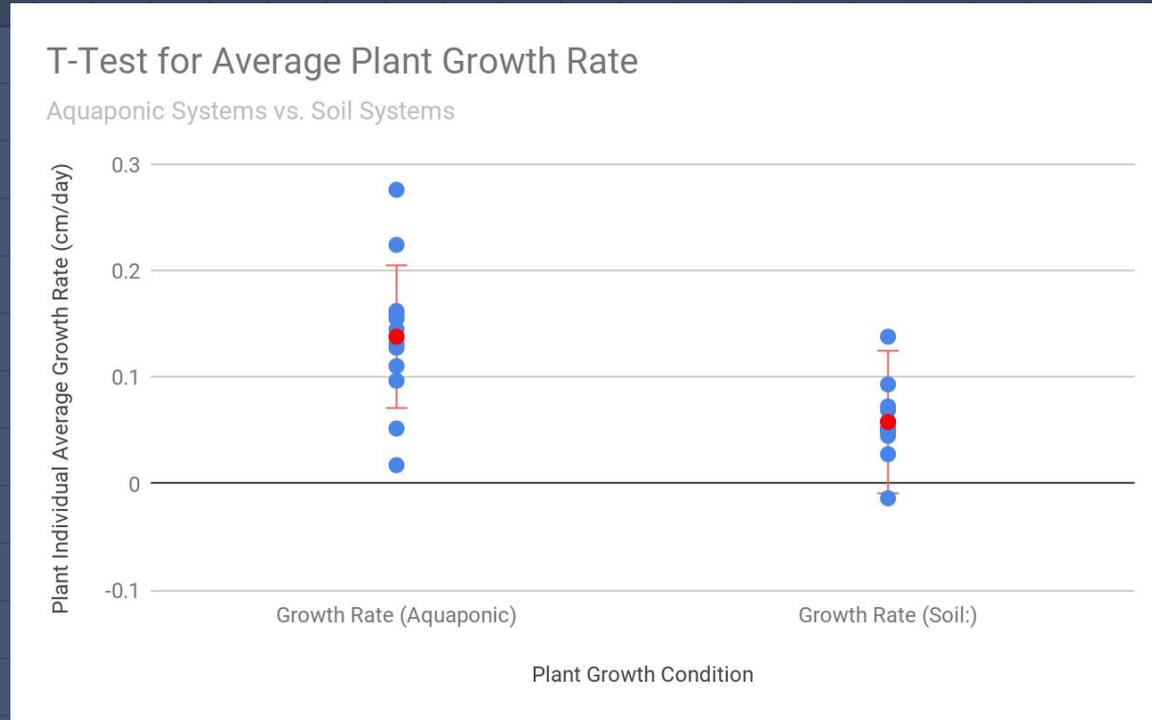


Results: Tank 6: Ammonia, Nitrate, Nitrite, pH



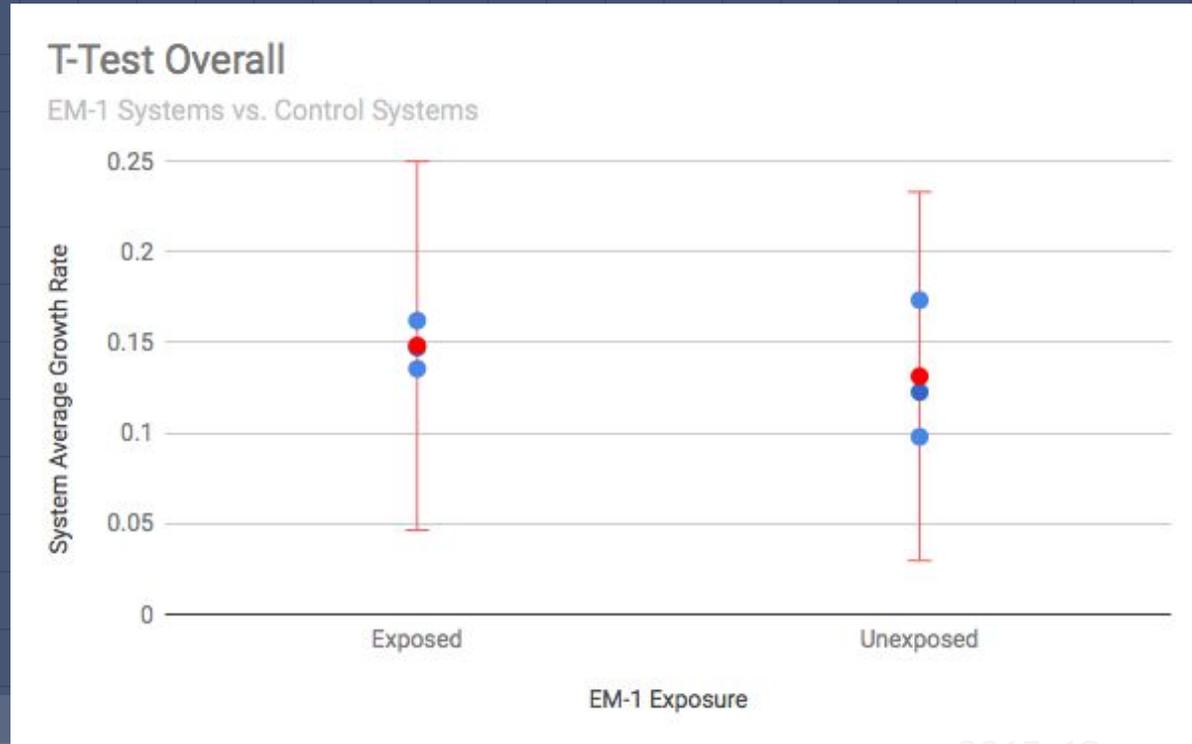
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The growth rate of the aquaponics beds were bigger than the growth rate of the controlled plants in the soil beds



2017-18

The addition of EM-1 Plant Growth Promoting Bacteria had no impact on the average rate of plant growth



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Future Questions

- What is the effect of basil on nitrate levels compared to other plants?
- What is the effect of feeder goldfish on nitrate levels compared to other fish?
- Does the temperature of the tank water affect the biochemical cycle?
- How will sample size effect significance tests on Em1 and no Em1?
- What is the significance tests results on temp, nitrate, and nitrite?

2017-18

A decorative horizontal line with five white circular dots is positioned at the bottom of the slide. Above this line, a thin white line with small open circles connects several points, creating a jagged path that spans across the width of the slide.

Now what?

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Extensions

What will we accomplish in the near future?

- Continue setting up aquaponics tanks.
- We are also planning to publish a paper!



Spreading Aquaponics to Other Classrooms

- Aquaponics changed the way we viewed science.
- We want to spread that experience!
- We have many ideas for spreading classroom aquaponics:
 - Making a class plan for this experiment.
 - Find ways to fund such experiments for other teachers.



Diversifying Aquaponics Beyond the Classroom

- Aquaponics greenhouse (CSA).
- Bigger systems help us expand our knowledge much quicker.
- Give back to the community; food bank type organization.
- Fund the project so we can invest in better analytic tools.



Questions?



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