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Creating a Sustainable Cycle with a Duckweed-Based Fertilizer
STEM Commercialization Plan

Part 1. Elevator Pitch

Commercially produced lawn and agricultural fertilizer results in runoff that pollutes ponds and other bodies of water. Duckweed, a small aquatic plant, can be grown in ponds to absorb the excess phosphorus and nitrogen that is a result of fertilizer runoff and nutrient pollution. The duckweed can then be harvested and turned into a sustainable fertilizer for lawns and crops.

Part 2. Executive Summary

A small aquatic plant native to Ohio called duckweed can increase the sustainability of fertilizer and decrease nutrient pollution and algal blooms. Duckweed is a bioaccumulator that can uptake nutrients such as nitrogen, phosphorus, and potassium from ponds. A bioaccumulator is an organism that absorbs chemicals and is unable to expel those chemicals as waste until it dies. By uptaking these nutrients, duckweed is aiding in the clean-up of nutrient pollution. However, when duckweed reaches saturation point and can no longer hold the nutrients, it releases them and dies. By harvesting duckweed, the excess nutrients are taken out of the ponds. When duckweed is harvested from the surface of ponds, it contains the same main nutrients as fertilizers. Therefore, duckweed can be used as a fertilizer on lawns and farms. The duckweed fertilizer was compared with commercial fertilizer on Zea mays, commonly known as corn, and produced similar results when analyzing the growth, the number of leaves, and dry mass. So, duckweed fertilizer can replace commercial fertilizers to create a more sustainable fertilizer and clean-up nutrient pollution in ponds.

Part 3. Problem Summary and Proposed Solution

The agriculture industry in Ohio is thriving, however, it is partly due to the fertilizers that add nutrients to the crops and produce larger and faster-growing yields. Common nutrients in fertilizers include nitrogen, phosphorus, and potassium. Runoff from agricultural and residential land is responsible for the nutrient pollution in local waterways such as ponds. The increase in eutrophication seen in algal blooms is correlated with the increased use of fertilizers. This eutrophication is a serious problem as it impacts the food chain and other organisms in the ecosystem. Beyond the environmentalist’s standpoint, the excess nutrients in watersheds, or areas of land directing water runoff into local waterways, provide homes with water. If the water runoff is contaminated with excess nutrients, it can be very costly to clean and if the water is not treated properly, diseases and health complications can arise.

However, duckweed can absorb common nutrients in fertilizers. If duckweed was farmed in polluted ponds, the excess nutrients would be uptaken by the duckweed, therefore effectively removing the excess nutrients. Then the duckweed could be harvested from the polluted ponds and turned into a highly-sustainable duckweed fertilizer for farms and lawns. The duckweed would have the nutrients for growth also common in fertilizers and has proven to be a reliable fertilizer for corn and other crops, but comes with a guaranteed environmentally-focused production. Duckweed can efficiently substitute commercial fertilizer as a naturally produced growth stimulant. This can change the fertilizer industry and introducing duckweed as a fertilizer will ensure safer agricultural practices.

Part 4. Summary of STEM Concepts & Principles Underlying the Overall Plan

Translating the use of duckweed into a viable fertilizer relies on three main STEM concepts. Duckweed’s ability as a natural bioaccumulator focuses this product on sustainability as this bioaccumulation is healthier for the environment than the synthesis of nutrients done to create commercial fertilizers. Duckweed’s simple structure includes a singular root system to absorb nutrients, making its bioaccumulation simple to foster. Duckweed is able to absorb nutrients in its surroundings that would otherwise remain in excess.

In developing an understanding of duckweed’s practical use as a fertilizer, the process of nitrogen fixation links its property of bioaccumulation of nitrogen to nitrogens' role in the growth of all crops. Zea mays is a great nitrogen fixer with a dependence on nitrogen for substantial nutritional value and success of growth, and is, therefore, the crop that duckweed fertilizer is tested on. Plants, upon different growth stages, will increase in growth rate rapidly upon an increase in prescribed and side-dress nitrogen, which is in the natural occurrence of the nitrogen cycle. Although nitrogen is abundant in the atmosphere, plants are only able to absorb this nitrogen once it is fixed. This fixed form is often prescribed with a fertilizer amendment to the soils in which it is planted. While in most soils, the nitrogen content is in an organic form, the plant is unable to take up the nitrogen in this form. It is the mineralization of nitrogen by microorganisms that makes it available for uptake by plants. Nitrogen is one of the most primary sources of nutrients in crops and is particularly necessary. NPK fertilization is the most favorable ratio of soil nutrients to the growth of crops with nitrogen being an important building block to proteins that form chloroplasts that host photosynthesis. Particularly the influence of nitrogen on chlorophyll is noticeable in Zea mays plants as it discolors the leaves and decreases nutritional value.

Dimensional analysis was also used in order to make sure that the amount of nitrogen in the duckweed fertilizer was equal to the amount of nitrogen in the commercial fertilizer. The amount of nitrogen had to be the same in the 100% duckweed treatment and in the 100% commercial fertilizer treatment so that each treatment's Zea mays could have an equal opportunity to take up nitrogen, as Zea mays is mainly a nitrogen taker. Dimensional analysis is a method of unit conversion and proportional reasoning where a given measurement can be multiplied by a known proportion to give a result of having a different unit. Dimensional analysis involves using conversion factors, which are ratios of related physical quantities shown in the desired units. In this experiment's case, the serving size of commercial fertilizer needed to be converted to what would be the serving size of duckweed fertilizer, all in terms of having the same amount of nitrogen. Measuring duckweed to produce a correct amount of duckweed fertilizer mass was vital to this experiment's testing design.

Part 5. Commercialization Assessment of the Overall Plan

Problem, pain point or market opportunity:

In society, most easily accessed commercial fertilizers are synthesized and unsustainable. When new nutrients are synthesized and are put on lawns and farms, the results can be devastating to nearby aquatic ecosystems. Nutrient runoff causes nutrient pollution, which can lead to algal blooms and polluted drinking water for animals and people. Some fertilizers are somewhat more sustainable, such as manure, yet the nutrients still continuously runoff with no clean-up plans in place.

Proposed solution:

Duckweed, on the other hand, is highly sustainable, easily accessible, and is already a part of aquatic ecosystems. Duckweed can be grown and harvested from ponds and then dried to be turned into a sustainable fertilizer. Duckweed is a bioaccumulator of excess nutrients that can be turned into fertilizer, and therefore is a great alternative to traditional commercial fertilizers as well as common natural fertilizers like manure. Added benefits of duckweed include prevention of algal blooms and rapid growth.

Target customers and intended users:

The targeted customers include farmers, lawn companies, and homeowners that would like to better their lawns and guarantee an environmentally safe way to do so. For the purpose of this commercialization plan, however, the target customers will be lawn owners because they will require smaller amounts of fertilizer, as opposed to farmers or lawn companies that would have bulk purchases that a small business that is just starting would likely not be able to handle. As the business grows, the target customers would expand to be anyone looking to purchase duckweed fertilizer, including small or large purchases.

Competitors:

Competitors of duckweed fertilizer would include well-known fertilizer companies like Scotts or Miracle Grow. Specifically, fertilizer companies advertising a sustainable fertilizer would be the biggest competitors, like organic fertilizer or manure fertilizers, because many of the lawn owners that would look into duckweed fertilizer would already want to help the environment and have more sustainable lawn management routines.

Customer value proposition & competitive advantage:

Duckweed fertilizer is quite possibly the most sustainable fertilizer because it creates a cycle in the environment. Duckweed is grown in ponds where it absorbs excess nutrients from the polluted water. Then, it is harvested, dried, packaged, sold, and applied on lawns. If duckweed is left in ponds too long, it reaches saturation point and releases the nutrients back into the water when it dies. So, by harvesting duckweed, excess nutrients that become harmful to the surrounding environment are taken out of the water and repurposed into a fertilizer. Another competitive advantage of duckweed is that it grows rapidly and will therefore produce a lot of fertilizer in a short amount of time.

Principal revenue streams expected:

If each bag was sold at $15 and 100 bags were made and sold, $1500 would be made, and considering operating costs of $864.36, the total profit would be $635.64. This would not include shipping costs, advertising costs, or the cost of property. After all of the initial materials are bought, duckweed truly defines itself as a weed as it grows exponentially. Duckweed would continue to grow after the initial materials are bought, aiding in profit growth and not adding many other expenses.

Principal startup and operating costs expected to be incurred:

To quantify the startup and operating costs, one must find out the plan for harvesting, preparing, and packaging the duckweed, and then base costs off of the plan. To harvest the duckweed, a net will be placed under the surface of the pond and lifted to skim the duckweed off the surface of the pond. To prepare the duckweed, the duckweed must be dried in an industrial drying oven. Then the duckweed must be blended in an industrial blender to reach a consistent texture. Finally, the duckweed must be packaged, preferably in environmentally friendly packaging consistent with the duckweed fertilizer's purpose. Then the product would be ready to ship. Variable operating costs would include shipping, advertisements, building for drying, blending, and packaging, as well as the cost of the farming land, including a natural pond and located near an area that has polluted water runoff. Duckweed is free as naturally obtained duckweed is frequently found throughout the ponds of Ohio, and the initial amount of duckweed will rapidly grow when farmed in a pond with nutrient pollution. From the previous year's experiment, 0.75g of duckweed per 203.2 sq. cm soil area is needed. Each bag would contain enough duckweed to fertilize 5000 sq. ft. (the Imperial System of Measurement was used to market the product in America). So, each bag would contain 37.7lbs of dried duckweed. Duckweed is 98% water, so a total of 18850lbs of wet duckweed would be needed to produce 100 bags of fertilizer. Startup costs are based on producing 100 bags of fertilizer, and the material costs are shown below.

Item	Amount	Brand	Cost
Ohio Farmer's License	1		$25
Product bags: biodegradable, child-safe	100	Alibaba.com	$30 ($0.30 per unit)
Industrial laboratory drying oven (1.5 cubic feet)	1	Amazon.com	$626.39
Ninja Professional 72 Oz Countertop Blender	1	Amazon.com	$89.99
330lb Industrial Postal Scale	1	Amazon.com	$42.99
Fine Mesh Pond Netting, 1/8″ Mesh	1, 15' x 20' sheet	The Pond Guy	$49.99

Duckweed	18,850 lbs wet weight	Rivers to Reefs Aquarium	$0

Total: $864.36

Part 6. Science and Technology Proof of Concept
Review and assessment of the scientific literature:
Duckweed structure and growth:

The common duckweed is a small plant found in many ponds and wetlands found in America, with the potential to help curb nutrient pollution and become a sustainable fertilizer source. Most often, they reproduce asexually by forming chains of new stems from vegetative buds, however, they can also reproduce by contact pollination because they live in dense areas (Fertig). Even though duckweed has a short lifespan of about five to six weeks, it grows in dense masses and can cover a pond like a blanket of snow (Lerner 2004). Duckweed is small, but it is rather complex considering it can help solve the runoff problem from the surface of ponds.

Duckweed is a hardy plant that grows well in many conditions, but better conditions can cause its growth to skyrocket. Duckweed thrives at a pH range of 6.5-7.5. Duckweed can grow at water temperatures between 6 and 33°C, but in water 30°C and above, duckweed's growth curve slows and stops at 33°C. Duckweed cannot grow in water too shallow because temperature fluctuations can be too harsh and stress the small plant. Water can be deeper than 0.5 meters, however, it is harder to manage harvest, and it needs to be harvested to become a fertilizer towards the end of its life when it reaches its saturation point (DUCKWEED: A tiny aquatic plant with enormous potential for agriculture and environment).

Duckweed has a straightforward body, similar to a leaf with a level top and a convex bottom. It is no larger than 6mm and it floats on still water. Its fronds contain flowers and a single root that stays in the water. Duckweed is typically in an elliptical shape, with no other stems or leaves connected to the duckweed except one unbranched root that has a shortage of vascular tissue. Fresh duckweed also contains about ninety-two to ninety-four percent water. Vascular tissue is the tissue in higher plants that makes up the vascular system, consisting of phloem and xylem, by which water and nutrients are conducted throughout the plant (Lerner, 2004). Duckweed sits on top of the water in clumps like most aquatic plants. In these clumps, it can block algae from growing (Administration of Bioponica). Not only can duckweed prevent and clean-up nutrient pollution, but it can also block the oxygen hog of algal blooms from growing.

Since duckweed can take up heavy metals from the water and has a high NPK ratio, it helps both plants and animals on the farm. Duckweed needs minerals in the water so that it can uptake them and grow. Duckweed's primary macronutrients are nitrogen, potassium, and phosphorus, while its secondary macronutrients are calcium, magnesium, and sulfur. Duckweed's micronutrients are aluminum, boron, copper, iron, manganese, sodium, and zinc. Plant tissue analysis reveals that duckweed contains the most amount of nitrogen at 16% nitrogen, 6% phosphorous pentoxide (P_2O_5), 16% soluble potash (K_2O), and 16% chloride (Pulido 2016). Nitrogen increases the growth of carotene, B vitamins, and cytokinin, specifically needed for plant growth (Johnston & Dowbenko 2004). Nitrogen is duckweed's main limiting nutrient as, without it, it cannot grow and thrive in its environment. Duckweed absorbs nitrogen best in the form of ammonium (DUCKWEED: A tiny aquatic plant with enormous potential for agriculture and environment). When organic matter breaks down (mineralization) the nitrogen ends up as ammonium (Sanderson, 2019). Water that is rich in nitrogen produces duckweed rich in protein, which is beneficial for fertilizer as well as animal food. Phosphorus makes up about 16% of duckweed's dry mass, but when water is rich in potassium, duckweed concentrates more potassium. Phosphorous is readily available for fertilizers or animal food once the duckweed dies. Small amounts of potassium are needed in duckweed growth as duckweed contains 6% potassium (Pulido 2016), but rapidly growing duckweed uses lots of potassium. Sulfur and sodium are also used by duckweed, but as of now, scientists do not know the significance of duckweed growth rates. Duckweed will also uptake and concentrate cadmium, chromium, zinc, strontium, cobalt, lead, aluminum, and even gold (DUCKWEED: A tiny aquatic plant with enormous potential for agriculture and environment). Duckweed needs lots of different nutrients to grow and survive and forms a good relationship with ponds as it can uptake nutrient pollution and can also provide nutrients to field crops.

Zea mays structure and growth:

Zea mays is a common crop that is easy to grow with strong popularity on Ohio farmlands. While the plant provides exceptional nutritional value, it's significance in testing a duckweed-based or supported fertilizer with it's supporting abilities to that of duckweed. The complex root system begins with the kernel of Zea mays in which the seminal roots emerge composed of lateral and radicle roots. Emerging from the tip of the kernel and the coleoptile of the kernel, respectively. The seed depends on the internal nutrients of the kernel until the nodal root develops and helps with water uptake from the soil. It is in this stage of root development that the fertilizer makes an impact in a safe transition and helps the nodal roots elongate from the crown of the plant to absorb nutrients from the soil and not usurp the reserves of the kernel, causing damage (Nielsen 2013). Above the seed and below the nodal roots is the mesocotyl that serves the plant by pushing the coleoptile towards the soil surface for the plant to sprout from the ground. Seeds planted two inches below the soil surface allows for ideal emergence time while still allowing the mesocotyl and nodal roots to mostly grow below the surface and not be at risk of damage from surface conditions (Hefty 2018). Later staged developments of root nodes push from above the soil, called brace, or prop, roots. These can take nutrients and water from the top layer of the soil and also provide the Zea mays with structural support. Zea mays are best grown with full sun exposure, good drainage, and in soils 15-20°C (Froelich 2013). Zea mays' progression through growth and stages of developing leaves is identified by the vegetation and reproduction stages. Referring to the plant by its leaf count with visible leaf collars gives the plant named stages as V2, V3, V4, etc. In emerging sprouts, the plant is considered in the VE stage of growth, and the last stage of VT of tasseling, until it begins the reproductive stages of producing its own kernels (Corn growth stages 2009). With particular necessities in its growth, fertilizer can increase the value of plant production.

Hypothesis:

Null Hypothesis: Zea mays mass and height will show no significant difference between treatments of fertilizer showing a duckweed fertilizer is just as effective as a commercial fertilizer. Any observed difference between the treatments is due to chance.

Design:

To test duckweed as a natural additive to fertilizer that would propose an efficient and safe flow of nutrients, an independent variable of the experiment tested were the different types and amounts of fertilizer being used; being the commercial fertilizer, duckweed fertilizer, and different combinations of the two. Specifically, there were six different treatments of fertilizer: 100% duckweed, 100% fertilizer, 40% duckweed with 60% fertilizer, 60% duckweed with 40% fertilizer, 50% duckweed with 50% fertilizer, and the control with no fertilizer. The dependent variable was the growth of Zea mays measured quantitatively as the height of the leaf arc. The independent variable was tested on the dependent variable by adding the different fertilizer treatments to identical groupings of Zea mays plants given the same treatments of water, light, soil, space, and temperature. It was predicted that the mixture of duckweed fertilizer and the commercial fertilizer at a 1:1 ratio would produce results as efficient as the commercial fertilizer, at a healthier standard. First, a natural duckweed fertilizer was produced, then used to create five different treatments with varying amounts of commercial fertilizer to duckweed fertilizer, in addition to a controlled group without treatment. The different treatments were added to the respective groups of Zea mays plants. For three weeks, the height, in centimeters, of each plant was measured at the end of a seven day period, then compared to determine the effectiveness of each treatment. Wet mass and dry mass recordings will analyze the specific growth of the root compared to the shoot of the plant.

Before beginning the experiment, the design of the testing was meticulous, identifying many prospective errors that had to be controlled to keep them from affecting the data. The Zea mays were grown in a greenhouse to control the heat and moisture. With the same lighting, water, and soil, the seeds placed in each of the wells were germinated before to ensure seed viability. Through the process of sprouting, a system of measuring that would not disrupt the plant or the soil and therefore influence the measurements was designed. By using a skewer and marking the starting soil amount, with each week, the new height of the leaf collar was marked and each measurement was recorded at the end of the growing period. This prevented the standard process of using a ruler along each plant from disrupting the soil settlement and reshape future measurements.

The fertilizers tested also had to compare in the different processes of releasing nutrients, slow or fast release. By using duckweed as a fertilizer, the nutrients were released slowly due to the structure with its outer shell, or skin, of the frond, and the slow process of decomposition. The slow-release fertilizers could be present in both the commercial fertilizer and the duckweed, while there are some fertilizer concentrations in the commercial fertilizer that would be effective more immediately than the slow release. When deciding how much of the commercial fertilizer and duckweed to use there had to be a guarantee that there was an even amount so that the 100% duckweed and the 100% commercial fertilizer would have the same chance at growing.

In order to set up a fair test, the amount of nitrogen was the base focus. How much commercial fertilizer to use in reference to the surface area of the plants was calculated, assuming that the fertilizer could penetrate five centimeters into the ground, as the commercial fertilizer is a fertilizer for grass and would, therefore, need to reach grassroots around five centimeters. Determining how much nitrogen was in this amount of fertilizer was used as the baseline 100% commercial fertilizer treatment. Then, this amount of nitrogen in duckweed was used as the conversion factor to use dimensional analysis to convert the units of nitrogen in fertilizer to the units of nitrogen in duckweed. This measured out the 100% duckweed treatment, and with both conversion factors, the amount of commercial fertilizer and duckweed fertilizer as a percent of the whole helped from the combination fertilizers.

Discussion:

Testing results:

Throughout the experiment, many observations were made regarding the wellbeing and growth of the Zea mays plants. Towards the beginning of the experiment, some plants were slower to sprout than others. Zea mays have a germination rate of 75% and so because 20 out of 140 plants did not sprout, the experiment had a sprouting rate of 92%. So, Zea mays not sprouting was expected, yet possibly because of the treatments of fertilizer and duckweed, a higher sprouting rate was achieved. Prior to planting, the seeds were germinated outside of the soil and only the seeds whose mesocotyl broke out were planted. While only the successfully germinated seeds were spread evenly and randomly, there were also shorter, malformed sprouts in some pots. Since there were some sprouts like this in every group, it can be concluded that this was due to random chance and was not correlated to the treatments.

To analyze the data, the means of each group of treatments within each week as well as a comparative analysis of the standard error of the means for each group are key observations. Under the six different treatments with forty plants in each test group, not all plants sprouted however with the amount that didn't sprout not making up as much of the whole of the test group, these values were excluded from calculations made, as the result of all forty Zea mays plants sprouting was primarily assumed to be a rare occurrence. In some cases, the mesocotyl may emerge from the kernel in different directions. It is the groups that differ in an amount not sprouted yet that show an impact that the treatment of fertilizer has on the plant. The standard error of the mean is the standard deviation of the sampling distribution of the mean. It is the accuracy of the distribution of data, or how accurate the mean of any given sample from that population is likely to be compared to the true population mean. The standard error bars overlapping explains that the difference between the two means is not statistically significant. With the standard deviation and means of the samples, measuring the coefficient of the variables shows the variability as defined by the standard deviation relative to the mean. Meaning, how much the standard deviation and error of the mean has to do with the total mean of the data. When the coefficient variability is a value less than one, there is low variability within the data. When the coefficient variability is a value greater than one, there is high variability within the data. In the results, each of the treatment groups for each week showed a coefficient variability of less than one, meaning the variance was slim in the data set [Table 1]. To conclude the value of the different treatments on plant growth, measuring the wet mass shows the nutritional mass of the plant. First taking the mass of ten randomly selected plants in each group (while eliminating those that did not emerge), the total wet mass was weighed, and secondly, by separating the root and the shoot of the mass, the two focal parts of the plants were analyzed in mass separately. The root to shoot ratio shows how much of the root was of the total mass of the plant. The plants with a greater root to shoot ratio means that the root was not as far from the mass of the shoot. Therefore, while all of the plants resulted in a shoot with a greater mass than the root, some provided a root that was in a ratio less significantly different from that of the shoot [Graph 1-4].

Lastly, ANOVA tests were taken to compare the means of the groups to see if the data could reject or fail to reject the null hypothesis. The degrees of freedom, or significance level, used was 0.05. If the p-value calculated by the ANOVA test was less than the significance level, then the null hypothesis can be rejected. The ANOVA test of height for week one had a p-value of 0.75, which is greater than the degrees of freedom, 0.05, meaning that the data fails to reject the null hypothesis. The ANOVA test of height for week two had a p-value of 0.00003 which is less than 0.05 meaning that the data rejects the null hypothesis. The ANOVA test of height for week three had a p-value of 0.1 which is greater than the degrees of freedom, concluding that the data fails to reject the null hypothesis and the results are statistically insignificant. However, week two produced results in which the p-Value was less than the degrees of freedom and therefore rejected the null hypothesis, concluding that the treatments were statistically significant. However, since this is an anomaly in the data, the significance must be a result of human error [Table 2]. For the ANOVA tests of dry mass, the control was not inputted into the test. The control was not included because the null hypothesis means that there is no significant difference in any of the data sets and the results needed to show that the null hypothesis failed to be rejected without the variability of a group without fertilizer. Furthermore, it was to ensure that the results between the groups of fertilizer had no true difference, which is what the null hypothesis is stating. In the ANOVA test done on the root to shoot ratio of the dry mass of Zea mays plants, the p-value was 0.43 which is greater than 0.05, failing to reject the null hypothesis. In the ANOVA test done on total dry mass, the p-value was 0.6, which is greater than 0.05, and also fails to reject the null hypothesis [Table 3]. Both ANOVA tests done on dry mass fail to reject the null hypothesis, showing that there is no true difference in the means of all groups with the independent variable of fertilizer, concluding that the duckweed fertilizer is a fair substitute for a commercial fertilizer in assisting the early development growth if Zea mays. Any amount of a duckweed fertilizer substitution is an elimination of an amount of chemically produced nutrients in commercially sold fertilizer today, making it steps closer to an environmentally friendly application.

Conclusions:

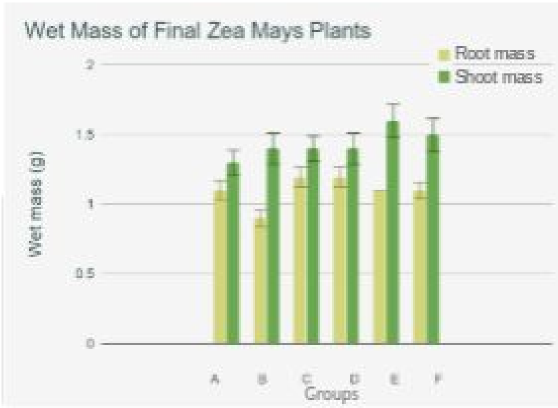
The duckweed fertilizer produced from harvested duckweed and oven-dried was used as a soil amendment on over 100 Zea mays plants, tested in varying combinations with commercial fertilizer as well as independent treatments for both fertilizers. The growth of the Zea mays plants was measured and recorded, noting leaf count and height weekly, and the wet and dry mass following the experimentation. The initial run of the duckweed-based fertilizer proved effective on the growth of Zea mays as the data failed to reject the null hypothesis that the duckweed fertilizer would be any less effective on the plant growth. However, failing to reject the null hypothesis in this experiment is subsequently supporting that the use of duckweed as a fertilizer is just as beneficial to plants in early growth as the commercial fertilizer since there was no statistical difference between treatments. The data overall did support that the early growth of Zea mays could be substantial with the use of a duckweed fertilizer that would provide similar nutritional values to the plant as a commercial fertilizer, at a safer cost to the environment.

When duckweed is grown on ponds, the duckweed sucks up nutrient pollution that is killing fish and other wildlife. Duckweed can also block algae from growing, preventing algal blooms. When this duckweed is harvested, effectively removing the excess nutrients from the polluted pond, the duckweed can be transformed into a fertilizer that could produce results similar to a commercial fertilizer that farm owners and lawn owners use. Then, the runoff from the duckweed's nutrients would runoff into ponds, and be reabsorbed by duckweed once again, so then it can be harvested and the nutrients can be recycled again and again. This sustainable cycle could be useful in neighborhoods where fertilizer is used on lawns and leaks into retention ponds, and also in farms where fertilizer runoff collects. This is different from using an all-natural soil amendment such as animal manure because yes, it provides a purpose for the animal manure, but the runoff from the nutrients in the fertilizer still ends up in ponds, polluting them. When using duckweed, environmental problems can be solved on the surface of the land and the water.

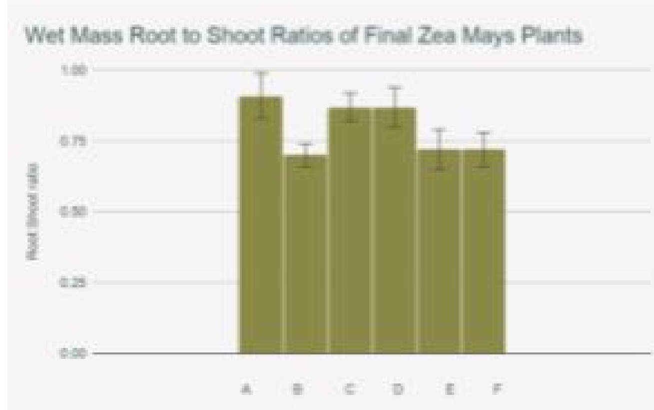
Data Tables/Graphs referenced in discussion:

Growth of Zea Mays Under Various Treatments of Fertilizer											
	Group A (100% duckweed)				Group B (100% fertilizer)				Group C (0% duckweed, 0% fertilizer)		
	Week 1	Week 2	Week 3		Week 1	Week 2	Week 3		Week 1	Week 2	Week 3
MEAN height (cm)	1.2	6.4	11.7		1.2	6.7	12		1.5	6.7	11.8
STDEV	0.49	2.13	2.26		0.59	2.16	2.92		0.69	1.85	2.55
SEM	0.09	0.37	0.38		0.11	0.36	0.48		0.08	0.21	0.28
COEFF of VAR	0.39	0.33	0.19		0.47	0.32	0.24		0.47	0.28	0.22
	Group D (40% duckweed, 60% fertilizer)				Group E (60% duckweed, 40% fertilizer)				Group F (50% duckweed, 50% fertilizer)		
	Week 1	Week 2	Week 3		Week 1	Week 2	Week 3		Week 1	Week 2	Week 3
MEAN height (cm)	2	7.4	11.3		2.2	8	13.2		2.3	8.2	12
STDEV	0.57	1.8	3.17		0.68	1.32	2.92		0.65	1.96	3.75
SEM	0.11	0.3	0.51		0.12	0.23	0.49		0.13	0.34	0.63
COEFF of VAR	0.29	0.24	0.28		0.31	0.16	0.22		0.28	0.24	0.31

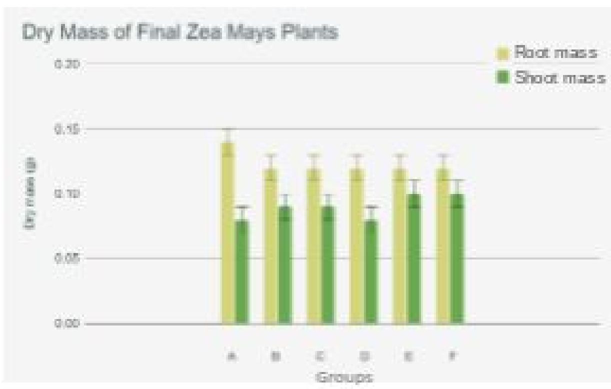
Table 1- The average height of Zea mays plants in various groups according to treatment recorded weekly over a span of three weeks. The standard deviation of the sampling distribution of the mean measuring the accuracy of the distribution of data. The coefficient of the variables shows the variability as defined by the standard deviation relative to the mean.



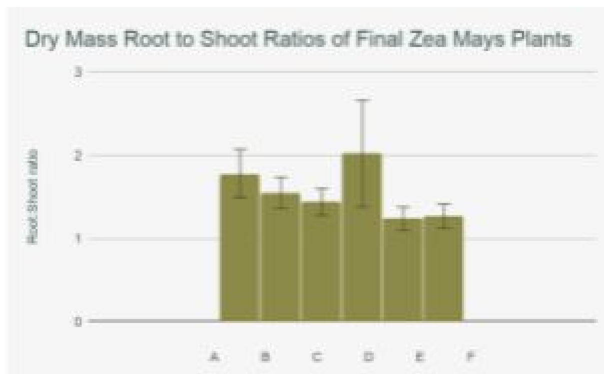
Graph 1- Average wet mass of final Zea mays separated by root mass and shoot mass per treatment.



Graph 2- Average wet mass of final Zea mays root to shoot ratios by treatment.



Graph 3- Average dry mass of final Zea mays separated by root mass and shoot mass per treatment.



Graph 4- Average wet mass of final Zea mays root to shoot ratios by treatment.

Anova summary- WEEK 1					
Source	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS)	F-Stat	P-Value
Between Groups	5	34.0347	6.8069	17.2462	0.75
Within Groups	173	68.2816	0.3947		
Total	178	102.3163			

Anova summary- WEEK 2					
Source	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS)	F-Stat	P-Value
Between Groups	5	99.2082	19.8416	6.1042	0.00003
Within Groups	204	663.1008	3.2505		
Total	209	762.309			

Anova summary- WEEK 3					
Source	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS)	F-Stat	P-Value
Between Groups	5	71.9446	14.3889	1.8257	0.109
Within Groups	214	1686.5758	7.8812		
Total	219	1758.5203			

Table 2- ANOVA test summary of Zea mays height to compare the means of the group and decide that the data fails to reject the null hypothesis, indicating its significance in quality to that of commercial fertilizer.

Anova summary- DRY MASS TOTAL					
Source	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS)	F-Stat	P-Value
Between Groups	4	0.003	0.0008	0.6873	0.6045
Within Groups	45	0.0498	0.0011		
Total	49	0.0528			

Anova summary- DRY MASS ROOT:SHOOT RATIO					
Source	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS)	F-Stat	P-Value
Between Groups	4	4.4642	1.1161	0.9777	0.4292
Within Groups	45	51.3673	1.1415		
Total	49	55.8316			

Table 3- ANOVA test summary of Zea mays dry mass to compare the means of the group and decide that the data fails to reject the null hypothesis, indicating its significance in quality to that of commercial fertilizer.

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Part 8. References

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