Algal Turf Scrubber Algae as a Soil Amendment Fertilizer

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Abstract

Several kinds of algal-based ecotechnologies are being studied for removing nutrients and sediments from polluted waters. Algae take up the pollutants through multiple mechanisms, and water quality is improved when the algal biomass is harvested. One of the benefits of this approach is that the harvested biomass is a byproduct of the water quality function and can be used in an economic process. In this study, data are reported on potential use of harvested algae to make a fertilizer. Building on earlier studies algae of known nutrient content that had been harvested from an algal turf scrubber in the Chesapeake Bay watershed, algae were added to potting soil in a plant growth experiment. The mass of algae added to the soil was scaled so that the amount of nitrogen added would be equivalent to the recommended commercial fertilizer application rate. Cucumber seeds were planted in the potting soil and their germination and plant height were compared between pots with algae fertilizer versus pots with a commercial fertilizer. Rates of plant growth were similar between the two treatments demonstrating the byproduct value of the algae as a fertilizer. Since the algae harvested from the algal turf scrubber contain some of the fertilizer nutrients that had runoff from farm fields, their return use to farms as a fertilizer can help to close the agricultural nutrient cycle in the Chesapeake Bay watershed.

Figure 1: Dried algal biomass from an ATS.

Introduction

Nutrient loading into water bodies is rapidly becoming a top concern around the world. There are many reasons why sediments and nutrients arrive at water bodies, but a large portion of this loading can be traced back to human activities (Nielsen 2002). There are numerous ways to address this pollution and one highly effective method is the Algal Turf Scrubber. The Algal Turf Scrubber (ATS) is an engineered water treatment system that removes nutrients from a water source via algae production (Adey *et al.* 2011). Through this process, there is a high potential for nutrients that can be removed from the water. Along with those benefits, ATS systems have simple designs which can be much less costly than other methods of treatment (Craggs 2001). For an ATS to perform efficiently, the growing algae must periodically be harvested from the system. In the past, there was not a practical use for the algae and it ultimately resulted in being burned. Recently, research has been done that analyzes the suitability of this algae as a fertilizer (Mulbry *et al.* 2005). Current literature demonstrates the potential of an algal fertilizer and its effectiveness under varying conditions. Using harvested algae as fertilizer could be very beneficial for farmers because they can use this algae at a very low price. Using algae as fertilizer can help the overall health of the water body and the environment as well. Instead of importing fertilizer from outside sources, farmers can use algae from local water bodies. By doing this, outside pollutants are eliminated thus creating a closed cycle. Overall, using algae harvested from the ATS seems beneficial to all parties involved. Other topics that must be addressed to perform this experiment are chemical composition of the algae and how different plants respond to algae grown in varying environments.

Methods

To test the null hypothesis that algae is an equally effective soil amendment to commercial fertilizers, multiple experiments comparing standard commercial fertilizer and the algae amendment were performed. During the course of three months, two different experiments took place. The first experiment contained 6 different treatments of fertilizer application with triplicates for each treatment in 6 inch pots with 80 grams of potting soil (Espoma Organic Seed Starter Premium Potting Mix). The first two treatments contained increasing amounts of commercial fertilizer Espoma Garden-Tone 3-4-4. Using the C:N ratio and application rate of the fertilizer, equal nutrient amounts of ground freshwater algae (~0.5 ppt of salt) from the Susquehanna River were added (Table 1). Lastly, a control with no added nutrients was tested.

The second experiment was set up similarly to the first. The main difference is that the algae used was sourced from brackish water (8-12 ppt of salt) from the Port of Baltimore. In addition, there were only two treatments of low (4.9 g) and high (23.1 g) algae amendment added. In total, there were 5 treatments including a control (Table 1).

The plant used in the experiment was cucumber (*Cucumis sativus*), which has a maturity of approximately 50-70 days. Over this period, the cucumbers were grown indoors in the Animal Science Building at the University of Maryland. The cucumber was kept at room temperature, under LED grow lights. During the both experiments, five seeds were planted 1 inch deep with 1 inch separating each seed to ensure germination. During both experiments, each plant was watered multiple times per week for 4 weeks.

After about 4 weeks in each experiment, the cucumbers were harvested and three metrics were measured and recorded for analysis. These metrics were for percent germination per pot (%), dry biomass (g) per pot, and plant height (cm) per pot. Each of the pots had a predetermined amount of seeds which was used to calculate the percent germination (number of seeds germinated/total number of seeds per pot). The weight of the above ground (soil to tip) dried plant biomass was measured. Before harvesting each plant, the average plant height per pot was recorded. All of these variables are good indicators of the viability of the soil.

Figure 2: Cucumber seeds germinating in petri dishes with their corresponding treatments.

T-tests were run to test significance between commercial fertilizer and algal fertilizer treatments for the three metrics of percent germination, plant height, and dry biomass.

Amount of Soil Amendment Added Per Pot

Nutrient Amounts	Control	Fertilizer Low	Fertilizer High	Algae Low	Algae Medium	Algae High
Experiment 1	0.0g	1.7g	3.3g	6.3g	12.4g	24.0g
Experiment 2	0.0g	1.7g	3.3g	5.9g	-	23.1g

Table 1: Different treatments of fertilizer and algae that were added to the soil medium of each pot.

Figure 3: Growth chambers for cucumber plants under LED grow lights.

Results

1. Plant Biomass

Experiment 1: The average dry weight of cucumber plants per 4 inch pot for the control group is 0.067 g. The mean plant biomasses for the low and high fertilizer groups were 0.07 g and 0.09 g respectively. Low, medium, and high algae plant groups ended with mean biomasses of 0.173 g, 0.163 g, and 0.163 g (Figure 4). T-tests with Alpha value of 0.05 were ran to determine significant difference in plant biomass between each algae and corresponding fertilizer groups. A t-test ran on the algae high and fertilizer high groups resulted in a p-value of 0.092. Therefore, we fail to reject our null hypothesis. A t-test for the low algae and fertilizer groups resulted in a p-value of 0.060, in which we also fail to reject the null hypothesis. Additionally, t-tests were run to compare the control with each experimental trial. The P values comparing the Control group with Algae Low, Algae Medium and Algae High were 0.141, 0.092 and 0.040 respectively. The P values comparing Control with Fertilizer Low and Fertilizer High were 0.333 and 0.477. Since the Alpha value used was 0.05, the only statistically significant difference in biomass was with the Control and Algae High group.

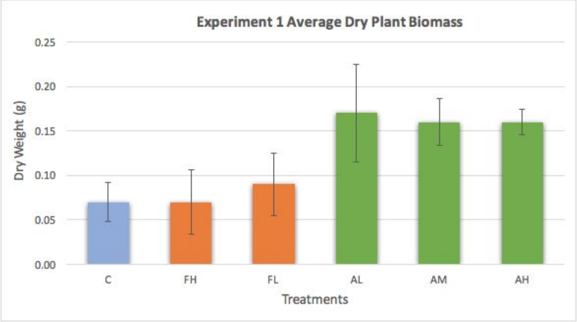

Figure 4: A comparison of dry weight (g) of cucumber plants in control treatments (C), 3.3g of fertilizer (FH), 1.7g of fertilizer (FL), and freshwater algae treatments 6.3g (AL), 12.4g (AM), and 24.0g (AH).

Experiment 2: The average dry weight of cucumber plants per 6 inch pot for the control group is 0.10 grams. The average weights for low and high fertilizer groups were 0.08 g and 0.11 g. Algae dry weights came out to be 0.14 g and 0.06 g for low and high nutrient concentrations, respectively (Figure 5). According to the t-test comparing Algae Low and Fertilizer Low, the p value was 0.06. Since the alpha value used was 0.05, there is no significant difference between treatments. According to the t-test comparing High Algae and High Fertilizer, the p value was 0.33, which states that there is no significance between the two groups. Additionally, t-tests were ran to compare the control with each experimental group. The P values came out to be 0.248 and 0.275 comparing the Control group with Algae Low and Algae High. The P values came out to be 0.284 and 0.429 comparing the Control group with Fertilizer Low and Fertilizer High, respectively. Since the alpha value to run these t-tests was 0.05, there is no statistical significance between the Control and Plant Height.

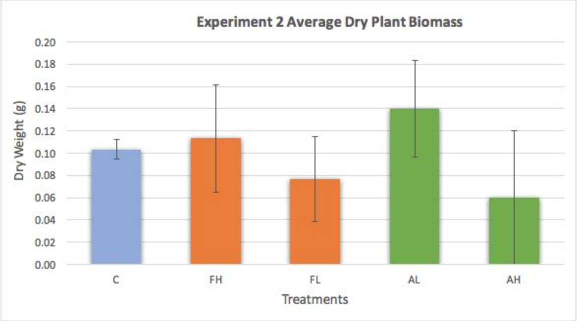

Figure 5: A comparison of dry weight (g) of cucumber plants in control treatments (C), 3.3g of fertilizer (FH), 1.7g of fertilizer (FL), and saltwater algae treatments 6.3g (AL) and 24.0g (AH).

2. Plant Height

Experiment 1: The mean plant height for the low and high fertilizer groups were 3.09 cm and 3.8 cm, respectively. Low and high algae plant groups showed a mean height of 3.25 cm and 3.77 cm. The Control group showed an average height of 3.5 cm (Figure 6). According to the t-test comparing Algae Low and Fertilizer Low, the p value is 0.29. According to the t-test comparing Algae High and Fertilizer High, the p value is 0.47. This shows in both concentrations of nutrients that there is no significance between plant height in algae and fertilizer treatments and we therefore fail to reject the null hypothesis. Additionally, t-tests were run to compare the control with each experimental trial. For the tests comparing the Control with Algae Low, Algae Medium and Algae High concentrations, the p values were 0.237 and 0.107 and 0.256, respectively. For the tests comparing the Control with Fertilizer Low and Fertilizer High, the P values were 0.099 and 0.292. Since the alpha value used was 0.05, this shows that in terms of height, there was no significance between the control groups and experimental groups.

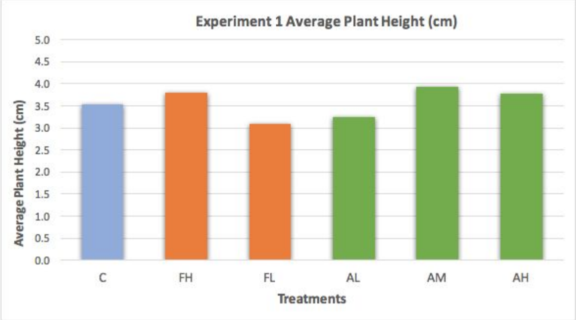

Figure 6: A comparison of height of cucumber plants in cm in control treatments (C), 3.3g of fertilizer (FH), 1.7g of fertilizer (FL), and freshwater algae treatments 6.3g (AL), 12.4g (AM) and 24.0g (AH).

Experiment 2: The mean plant height for the low and high fertilizer groups were 4.9 cm and 5.5 cm, respectively. Low and high algae plant groups showed a mean height of 5.1 cm and 5.5 cm. The control plant height came out to be 3.5 cm (Figure 7). In a t-test comparing algae low and fertilizer low samples, the p-value came out to be 0.44. This shows that there is no significant difference between the two experiments which had the same nutrient concentrations. In a t-test comparing algae high and fertilizer high concentrations, the p value came out to be 0.39, which also shows there is no significant difference. Additionally, t-tests were run to compare control with each experimental value. The p values came out to be 0.006, 0.035, 0.178 and 0.040 comparing the Control with Algae Low, Algae High, Fertilizer Low and Fertilizer High concentrations. Since the Alpha value used was 0.05, this shows that the only statistically significant difference in plant height was with the Fertilizer High experiment group.

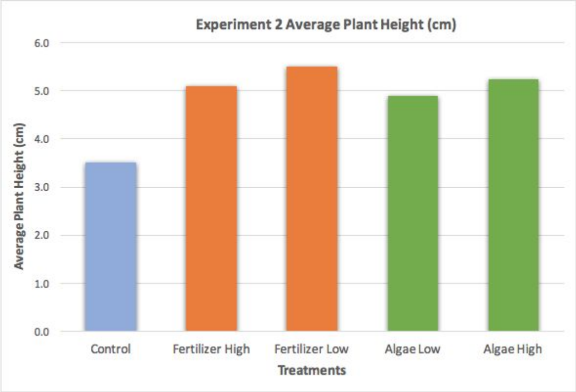

Figure 7: A comparison of height of cucumber plants in cm in control treatments (C), 3.3g of fertilizer (FH), 1.7g of fertilizer (FL), and saltwater algae treatments 6.3g (AL) and 24.0g (AH).

3. Plant Germination

Experiment 1: The Control group's average plant germination came out to be 53.3%. The average plant germination percentage for Algae Low, Algae Medium and Algae High was 86.7%, 86.7% and 86.7%, respectively. For Fertilizer Low and Fertilizer High experimental groups, the average germination came out to be 73.3% and 60.0% (Figure 8). When comparing the same nutrient concentrations with t-tests, the P value comparing Algae Low and Fertilizer Low was 0.317. When comparing Algae High and Fertilizer High, the P Value was 0.029. Since the Alpha used was 0.05, this shows that there is a statistical significance only between Algae High and Fertilizer treatments.

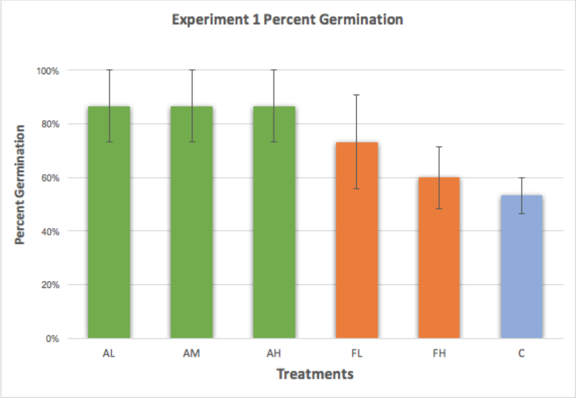

Figure 8: Percent of seed germination in cucumber seeds placed in freshwater algae treatments of 6.3g (AL), 12.4g (AM), 24.0g (AH), fertilizer treatments of 1.7g (FL) and 3.3g (FH), and the control treatment (C).

Experiment 2: The Control group's average plant germination came out to be 73.3%. The average plant germination percentage for Algae Low and Algae High was 26.7% and 13.3%. For Fertilizer Low and Fertilizer High experimental groups, the average germination came out to be 26.7% and 33.3%, respectively (Figure 9). Compared to our first experiment, the percent germination all around the board was significantly lower in the experimental groups. In comparing experimental groups with the same nutrient concentrations with t-tests, the p value for Algae Low versus Fertilizer Low was 0.500. The p value comparing Algae High and Fertilizer High was 0.211. In conclusion, since the Alpha value used was 0.05, there was no statistical significance in the difference of percent germination among the groups.

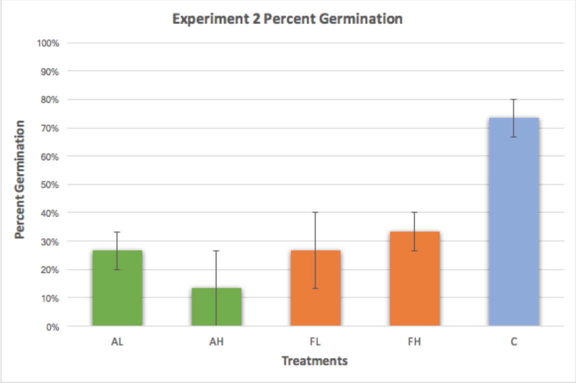

Figure 9: Percent of seed germination in cucumber seeds placed in saltwater algae treatments of 6.3g (AL), 24.0g (AH), fertilizer treatments of 1.7g (FL) and 3.3g (FH), and the control treatment (C).

Figure 10: All cucumber plants after 4 weeks of growth in experiment 1. Treatments from left to right in triplicate: control, algae high, algae medium, algae low, fertilizer high, fertilizer low.

Discussion

Our results show that the ATS biomass is equally effective at enhancing plant biomass development when compared to a commercial fertilizer with equivalent nutrient quantities. Both the algae and commercial fertilizer increased plant yield at a similar rate. These results suggest that ATS biomass could be used as a fertilizer substitute. Using algae from an ATS system that removes the excess nutrients from the watershed could eliminate the need for commercial fertilizer while simultaneously closing the nutrient loop.

The source of the algal biomass (brackish water algae vs. freshwater algae) should be considered when determining whether an algae will be an effective fertilizer.

It should be noted that error may have occurred during experiment 2 with brackish water algae, seeing as there was a large standard error among treatments. Also, no plants grew in two of the pots that had fertilizer added; it is highly unlikely that this occurred due to random error. It also appears that the plants that were grown with brackish water algae as a soil amendment has a lower average plant dry biomass, and this is most likely due to the higher salt content (8-12 ppt) in the brackish water algae acting as a growth inhibitor on the plants by preventing water uptake.

Previous studies by Mulbry *et al.* (2005, 2007) have shown that biomass from ATS systems have consistent mineralization values. In line with these Mulbry et al. (2005, 2007) studies, algal biomass and commercial fertilizer were able to provide equal amounts of N and P to growing plants.

Although this experiment took place in a small-scale laboratory setting over a relatively short period of time, the results suggest that ATS biomass could be used in large scale agricultural systems, thus closing the regional nutrient cycle and reducing the need for excess nutrients via fertilizers, while simultaneously saving money on highly expensive technologies to clean water bodies. Using ATS biomass in a large scale agricultural setting would require further research and time.

The use of ATS biomass as a fertilizer is promising for the future of regional watersheds as it has economic, environmental, and social benefits. Using the ATS biomass as an algal based fertilizer will significantly decrease the total regional cost of fertilizer, while removing pollution from watersheds and increasing water quality for recreational use. Further experiments with longer time periods could be done to explore the quality of the plant when grown to maturity.

References

Adey, W., C. Kangas, P., & Mulbry, W. (2011). *Algal Turf Scrubbing: Cleaning Surface Waters with Solar Energy while Producing a Biofuel* (Vol. 61). https://doi.org/10.1525/bio.2011.61.6.5

Adey, W. H., Laughinghouse, H. D., Miller, J. B., Hayek, L.-A. C., Thompson, J. G., Bertman, S., Hampel, K. and Puvanendran, S. (2013), Algal turf scrubber (ATS) floways on the Great Wicomico River, Chesapeake Bay: productivity, algal community structure, substrate and chemistry[1]. J. Phycol., 49: 489–501. doi:10.1111/jpy.12056

Mulbry, W., Westhead, E. K., Pizarro, C., & Sikora, L. (2005). Recycling of manure nutrients:
use of algal biomass from dairy manure treatment as a slow release fertilizer. *Bioresource Technology*, *96*(4), 451–458. https://doi.org/10.1016/j.biortech.2004.05.026

Mulbry, W., Kondrad, S., & Pizarro, C. (2007). Biofertilizers from algal treatment of dairy and
swine manure effluents: characterization of algal biomass as a slow release fertilizer.
Journal of Vegetable Science, *12*(4), 107-125.

Nielsen, Karina J. “Nutrient Loading and Consumers: Agents of Change in Open-Coast Macrophyte Assemblages.” Proceedings of the National Academy of Sciences, National Acad Sciences, 9 June 2002. Doi: 10.1073/pnas.0932534100