UNIVERSITY OF WISCONSIN SYSTEM
SOLID WASTE RESEARCH PROGRAM
Student Project Report

Use of Compost Tea as a Nutrient Amendment for Plant Growth in a Re-Circulating Hydroponic System

May 2010

Student Investigator: Brian Leudtke
Faculty Supervisors: Dr. Robert Michitsch & Dr. Aga Razvi

University of Wisconsin-Stevens Point

List of Tables and Figures

Introduction

Background

In today's world there are concerns with accumulating waste, limited amounts of freshwater and fossil fuels, decreasing biological diversity, and world hunger. To meet our increasing food needs we have developed various methods of agriculture. Agriculture is a major culprit in all of the previously mentioned categories (Morris 2002). Modern agriculture produces sustenance for our people and animals, yet it has some environmental consequences. Release of nutrients to the environment can lead to many negative effects. Hydroponics is an efficient way of producing food with maximum efficiency of nutrient uptake by plants as the solution is completely controlled. Compost tea has been used for centuries, evidence indicates that it has been used since the Roman Empire (Ingham 2002). Compost teas are a sustainable, economic, and feasible way to efficiently utilize nutrients from pre and post consumer food waste and vegetative wastes from modern agriculture. Compost tea is an umbrella term referring to a nutrient and/or microorganism rich solution prepared by releasing compost nutrients and microbiology into solution. Recently, compost teas have been recognized for their ability to suppress several foliar diseases as well as seed and root rot (Scheuerell 2004). A compost tea can be tailored to its desired use. For example a compost tea can be specifically brewed for use as a soil organic matter builder, a disease suppressant, or a nutrient source (Ingham 2002).

Little work has been done to assess the nutritional benefits of compost teas on plant growth (Pant 2009). Strawberry yields were increased with the application of an aerated compost tea compared to a control solution (Welke 2009). Vermicompost tea increased plant production and mineral nutrient content in pak choi (*Brassica rapa* cv. Bonsai Chinesis group; Pant 2009).

Compost teas can be prepared in several ways, aerated compost tea (ACT) and non-aerated compost tea (NCT) have been evaluated for their effect on disease suppression. In some studies aerated compost tea has shown impressive results in disease suppression while NCT has not (Ingham

2002; Scheuerell 2004; Welke 2009). Aerated compost teas produced at low temperatures with stable compost produced less phytotoxicity than teas produced using other methods with composts of less stability (Carballo 2009).

Hydroponics is the art of growing plants in a soilless medium. Commercial organic hydroponic food production is still in its infancy. Natural sources of macro-nutrients need to be assessed and combined with natural sources of micro-nutrients at proper levels to produce a formulation that provides all the elements necessary to sustain acceptable commercial plant growth (Jones 2005). Adding one gallon of compost tea to every 50 gallons of hydroponic nutrient solution to prevent disease is also suggested (Ingham 2002).

Closed system hydroponics is a method of hydroponic culture in which the nutrient solution is re-circulated throughout the system. Traditional systems are termed “open” systems where the solution is passed through the rooting medium once then discarded. Closed system or re-circulation systems are gaining attention due to their cost and waste minimization properties. Purvis et al. (1999) found that re-circulating of nutrients in a closed system reduced N, P and, K additions by 57-77%.

Experimental Design

A commercial compost was obtained from Growing Power's Milwaukee, WI urban farm. Growing Power's compost is the product of many pre and post consumer food waste products. Some of these wastes were: brewery mash, coffee grounds, bad grocery produce, animal wastes and, yard clippings.

This compost was used to create an ACT (200 g /L) which was aerated for 48 hours. Compost teas were brewed every two week during the trial. A control solution composed of Plant Prod 18-9-27 (0.55 g/L; Plant Prod 2001) hydroponic solution was prepared for a comparison. Solutions were stored in aerated reservoirs and pumped to the grow tubes where plants were suspended in mesh plastic baskets (Figure 7). A 12 cm depth of solution was maintained in the growing tubes, all excess solution would drain back into the reservoir.

Wisconsin FastPlants^{TM} (*Brassica rapa*) were grown in a re-circulating, ebb and flow hydroponic system(picture in appendix). Wisconsin FastPlants^{TM} were used for their small size, quick life cycle and, availability.

The experiment took place in the University of Wisconsin - Stevens Point (UWSP), College of Natural Resources greenhouse. Seeds were placed in the rockwool rooting medium February 8, 2010, placed in the the growing tubes February 23, 2010, and destructively harvested April 3, 2010. Both compost teas and control solutions were completely replaced every two weeks throughout the experiment.

Analysis of the compost for C:N was performed at UWSP using a C:N analyzer. Elemental analysis was conducted for the compost tea and control solutions at experiment start. Compost teas were sent in for additional elemental analysis before and after each solution change (ie. every two weeks). Ammonium and nitrate were tested separately during the duration of the experiment in order to balance the N content of the compost tea and control nutrient solutions. At the end of the experiment plants were harvested, dried, and sent to the University of Wisconsin- Madison Plant and Soil Analysis Laboratory for elemental analysis.

Methods

Compost Tea

Compost was mixed in a large plastic drum to insure a homogeneous mix. The compost was kept in a refrigerated condition to maintain consistent tea production by slowing microbial activity. Prior to brewing, the compost was put through a 0.64 cm sieve to remove any unnecessary large fragments. Compost was placed into 19 L buckets at a rate of 200 g per liter(Figure 4). Each bucket (5 in total) was filled with 15 L of de-ionized water and an aerator placed in each. The compost tea brewed for 48 hours. A total of 90 L of compost tea was brewed per solution change then added to the system reservoir, which was also aerated. The control nutrient solution (Plant Prod 18-9-27) was prepared by mixing 16.7 g of Plant Prod to 30 L of de-ionized water. Solutions were removed every two weeks and replaced by a fresh solution twice after the initial setup for the duration of the experiment following the above methods.

The hydroponic system being used to conduct the experiment was an ebb and flow style re-circulating system with four tubes in total. Each tube held four plants and one access port. A submerged pump brought solution into the tubes which upon reaching a desired level was then drained back into the reservoir (Figure 5).

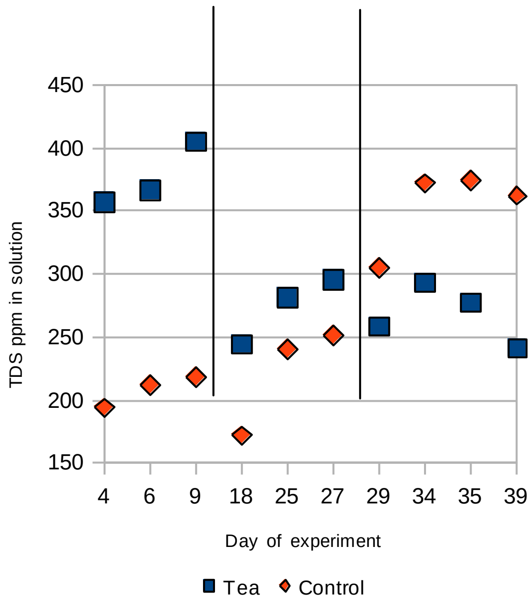
Wisconsin FastPlants™ (*Brassica rapa*) were seeded into rockwool cubes (two seeds per site) one week prior to the beginning of the trial. Upon experiment start the seedlings were placed into 3 inch netpods filled with hydroton pellets located in the hydroponic system (Figure 6).

Three of the four tubes in the hydroponic system were filled with compost tea and one tube was filled with the control solution. Samples of the compost, compost tea, and control solution were taken and sent in for analysis initially. Before and after each solution change samples of the compost tea were taken and sent in for analysis. The hydroponic system was operated manually being filled and drained one to two times per day. Total dissolved solids and temperature readings were performed throughout the experiment. A hand held Sunleaves® TDS unit was used to perform TDS tests. Temperature was assessed using a digital thermometer. Upon experiment termination plants were destructively harvested (roots were separated from the tops), dried, and sent in for elemental analysis.

Results

Compost

Nitrate and Ammonium were tested for in the compost, compost tea, and control solution during the first day of the trial. Compost had a C:N of 11.91, pH of 7.4, and a soluble salt content of 1.51 dS/m.



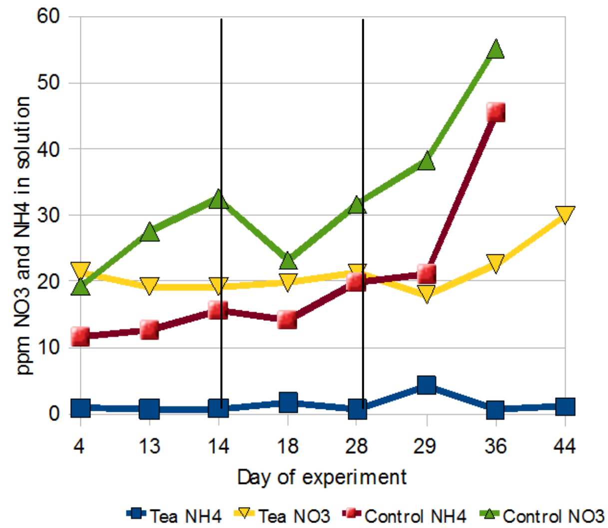


Figure 1. Total dissolved solids (TDS) measured using a Sunleaves TDS meter. Nitrate and ammonium concentrations determined by Kjeldahl distillation. Hydroponic solution were flushed on 03/10/10 and 03/23/10 represented by vertical lines on the graphs.

Compost Tea

Nitrate and Ammonium in solution remained fairly stable throughout the trial with an increase in NO_3 in the last week. Fluctuations in pH occurred throughout the trial with a low of 7.6 and high of 8.3. Chloride levels decreased from 50.9 to 31.1 ppm and sulfur levels decreased from 21.69 to and 14.81 ppm. Total dissolved solids (TDS) decreased over the duration of the trial. After each solution change TDS increased slightly. A table with elemental analysis values is available in the appendix.

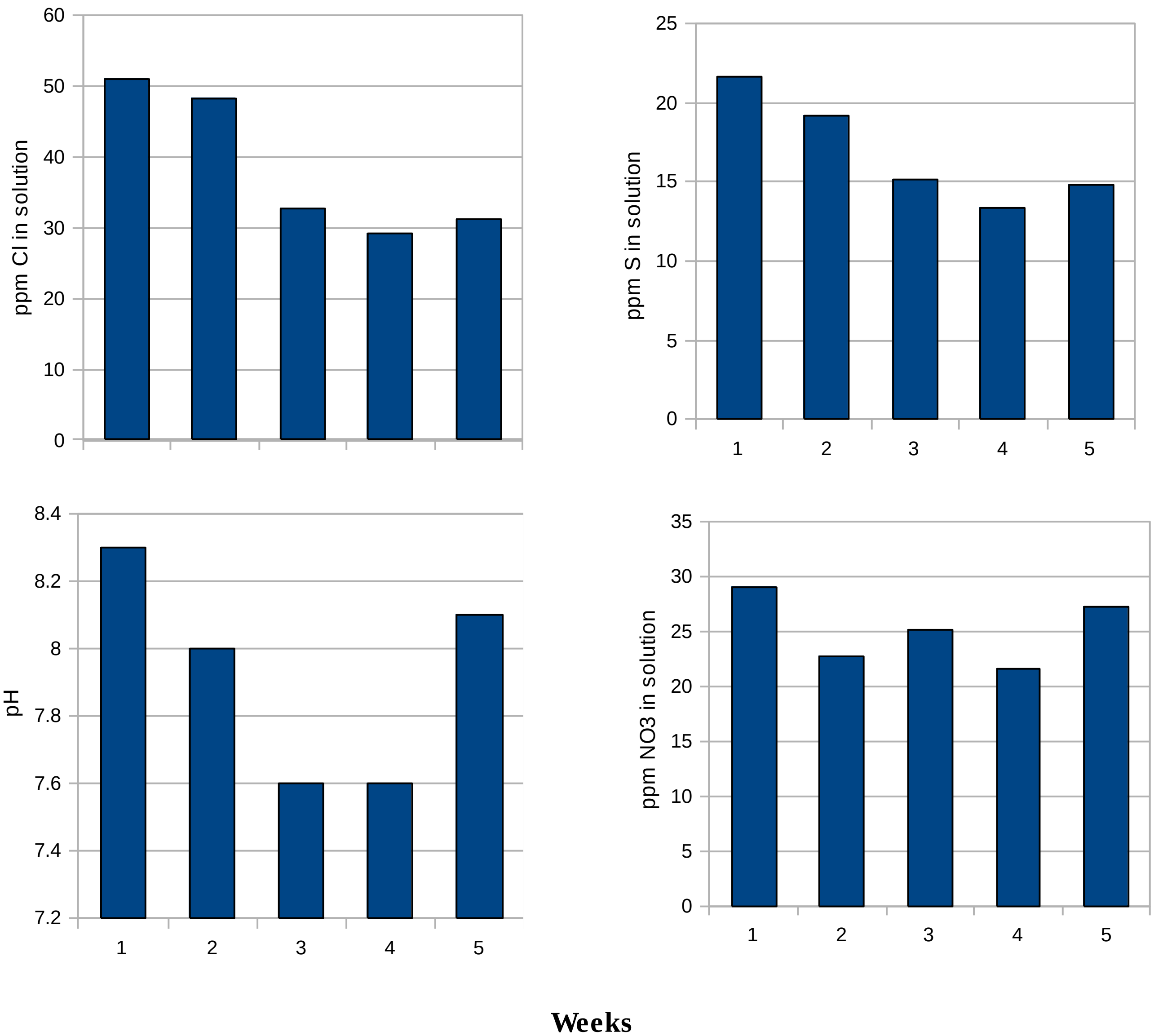


Figure 2. Elemental analysis performed by the UW-Madison Plant and Soil Analysis Laboratory. Bar's 1 and 2 are samples taken from the beginning and end of the initial solution. Bar's 3 and 4 are samples taken from the beginning and end of the second solution. Bar 5 is a sample taken from the end of the third solution.

Plant

All plants (except for one which died during week 3) completed their life cycles. The control treatment yielded greater dry mass than the compost tea treatment (3.55 g for control, 2.36 g, 2.36 g and, 2.51 g for compost tea respectively). Plants grown in the control solution were higher in N, P, K, Mn, Fe, and B (table 1) when compared to the compost tea treatment. Plants grown in the compost tea had higher amounts of Na, Ca, Mg, Zn, and Cu when compared to the control.

Table 1. Plant elemental analysis of plants from tubes A-D. Tubes A-C were grown in compost tea while tube D was grown in the control solution. Spinach mustard (*Brassica pervirdis*) suggested dry plant elemental concentration ranges provided for comparison.

	N %	P %	K %	Ca %	Mg %	S %	Zn ppm	B ppm	Mn ppm	Fe ppm	Cu ppm	Al ppm	Na ppm
A Tea	3.54	0.7	4.04	2.06	0.41	1.26	72.83	54.42	27.91	60.57	6.37	12.55	3174.2
B Tea	2.74	0.54	3.39	1.82	0.4	0.78	65.44	57.94	32.58	61.34	5.73	7.89	3990.67
C Tea	3.39	0.77	4.12	2.15	0.44	1.17	67.69	67.38	32.97	57.76	5.7	11.21	3244.93
ABC Avg.	3.22	0.67	3.85	2.01	0.42	1.07	68.65	59.91	31.15	59.89	5.93	10.55	3469.93
D Control	6.14	1.1	5.7	1.04	0.14	1.18	43.13	74.78	136.87	106.99	3.05	10.9	990.26
Spinach mustard^T	2.64-4.19	.3-.53	3.08-4.44	1.43-3.03	0.17-.32	.53-.87	23-31	20-31	28-49	74-231	4 – 6	104-545	166-363

Spinach Mustard^T: *Brassica pervirdis,* (a similar species to *Brassica rapa*.) suggested concentrations

Discussion

Compost Tea

Nitrate and ammonium were tested for regularly by Kjeldahl distillation throughout the experiment (figure 1). Ratios of greater than 9 parts NO3 to 1 part NH4 show an increase in pH over time. When NO3 is in high quantity compared to NH4 essential elements are more readily taken up by plants (Jones 2005). On average the NO3:NH4 was 16:1 in the compost tea (CT) for the duration of the experiment.

Total dissolved solids (TDS) tended to increase after each solution change in the CT despite the negative trend overall. This can be attributed to microorganisms releasing ions into solution, and evaporation concentrating the solution overtime between changes. The decreasing overall trend can be attributed to variations in compost as it continues to breakdown over time.

Hydroponic nutrient solutions were compared to a well known hydroponic solution, the Hoagland's “modified” solution. Macro nutrients in compost tea were lower than suggested by Hoagland's “modified” solution. Micro nutrients (excluding Na) in compost tea were in excess compared to Hoagland's "modified" solution. Nutrient concentrations decreased over time between solution changes due to plant uptake. The high micro nutrient concentrations and low macro nutrient concentrations can explain the lower amount of biomass produced by the compost tea treatment compared to the control. When excess salts are in solution plants have a harder and harder time absorbing water and needed nutrients (Hopkins 1999). The CT plants had much higher concentration of Na in their tissue, well over the suggested concentration(table 1). This can cause nutritional deficiencies and toxicities which can lead to stunted growth, necrosis, and eventually death. High Al concentrations can be attributed to the use of woodchips during the composting process. Woodchips can be high in Al which would be released during decomposition. Woodchips and stones were removed from the compost prior to tea making by filtering through a 0.64 cm sivve.

Table 2. Elemental analysis results from UW-Madison Plant and Soil Analysis Laboratory. Hoagland's "modified" solution provided for comparison (Michitsch). All values except pH are in ppm. Tea1 represents the first batch of compost tea, Tea two represents the second batch, and Tea3 the final batch.

	pH	NO_3	P	K	Ca	Mg	Cl	SS^T	S	Zn	B	Mn	Fe	Cu	Al	Na
Control	7.2	44.16	23.13	127.13	0.86	0.15	3.3	0.64	7.27	0.12	0.09	0.47	0.62	0.04	0.05	5.86
Tea1	8.3	29.04	6.27	82.55	39.2	20.18	50.9	0.79	21.69	0.37	0.01	0.66	33.37	0.1	44.1	110.84
Tea1	8	22.8	5.38	70.4	34.12	17.96	48.3	0.76	19.22	0.3	0.12	0.51	25.7	0.12	32.9	93.81
Tea2	7.6	25.12	5.88	88.28	43.44	17.57	32.6	0.59	15.18	0.27	0.15	0.44	22.14	0.11	28	29.62
Tea2	7.6	21.68	5.83	84.11	37.9	17.27	29.1	0.54	13.41	0.28	0.14	0.49	22.9	0.1	30.59	21.87
Tea3	8.1	27.2	6.96	96.24	46.96	21.73	31.1	0.63	14.81	0.42	0.19	0.8	36.92	0.11	43.66	22.32
Hoaglands "modified"		105	15.5	118	180	24	302		106	0.03	0.25	0.25	4.5	0.01		193

SS^T:Soluble Salts

Plants

Plants grown in the CT completed their life cycles and appeared visually healthier, although smaller, than the control treatment (Figure 3). Plant analysis showed that nutrient concentrations in tissues were in the acceptable range for all elements except for Na. Levels of Na in the CT were much higher than levels in the control solution, yet Na in both the CT and control were low compared to the Hoagland's solution. For CT, Na could have been the limiting factor for biomass production. The control treatment returned excessive amounts of N, P, K, B, and Mn, while Ca and Cu were low. This indicates that the control solution was prepared too strongly for optimal *Brassica rapa* growth.

Conclusion

Plants were grown successfully in the compost tea (CT). All plants completed their life cycles, producing flowers and seed pods by the termination of the trial. Elemental analysis of plant tissue showed that plants grown in CT had concentrations of nutrients in the acceptable range except for Na which was found in excessive concentrations. The extremely high Na content likely reduced plant growth by reducing the ability of the plant to translocate water and nutrients (Hopkins 1999). Plants grown in CT were smaller, but healthier in appearance than plants grown in the control solution. It is recommended that the solution should be diluted to an acceptable Na content for future trials. Although the decrease in concentration of other elements may cause deficiencies and limit growth potential. A compost source low in Na may produce a more effective CT.

Plants grown in the control solution grew large and completed their life cycles, however they did not appear to be completely healthy. The control solution showed deficiencies in some micro nutrients (Figure 7) and should be amended with a micro nutrient fertilizer to reach appropriate levels. Interestingly the nutrients present in large amounts in one were slightly lacking in the other. Further research should be conducted to determine how the CT and control (ie. inorganic hydroponic solutions) solutions interact and the effect of the control solution on the microbial populations in the CT. A combination of both CT and control solutions if feasible could be a step forward in discovering a perfect hydroponic nutrient solution as described by Jones (2005).

Further research should also be conducted using a different plant species. Wisconsin FastPlants™ (*Brassica rapa*) are not a popular commercial species with few data sets available for comparison (ie. nutritional requirements, recommended nutrient concentrations in dry tissue). Without good data comparative data conclusive evidence on the success of a compost tea is difficult. Performing full elemental analysis of the solutions every day or every other day over the course of the experiment would produce interesting results as to how the solutions change over time with respect to microbial populations life cycles.

The hydroponic system used clear vinyl tubing to aid in identifying clogged sites and observe any colonization by microorganisms. The nutrient and light rich tubing became the home to algae, turning the tubes from clear to tennis-ball-green (Figure 8). Coating the tubing in a white tape, then black tape, then white tape would block out any light and not absorb heat, and should therefore minimize algal colonization. This would make clog identification difficult. A better method would be to cover the tubing in a easily removable, light blocking sleeve to allow for clog detection and removal, even a folded opaque plastic sheet would be beneficial. Algae and a brown rot began to colonize the tops of the rockwool cubes (Figure 7). A simple covering of either plastic sheeting or an opaque lid cut to size could eliminate this issue.

Between the two week solution changes evaporation reduced solutions by as little as 10 L to as great as 30 L. Modifying the hydroponic system to have fewer open air locations and adding more solution initially could be beneficial to maintaining a more consistent amount of solution in the system.

Appendix A Tables and Figures

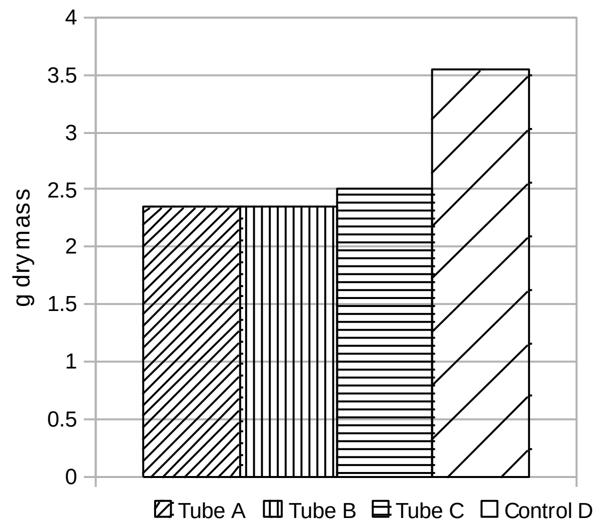


Figure 3. Plants were dried at 70° C for 48 hours and weighed. Tubes A-C were re-circulated with compost tea while Control D was re-circulated with the control solution.

Figure 4. Aerated compost tea brewing in the UWSP greenhouse.

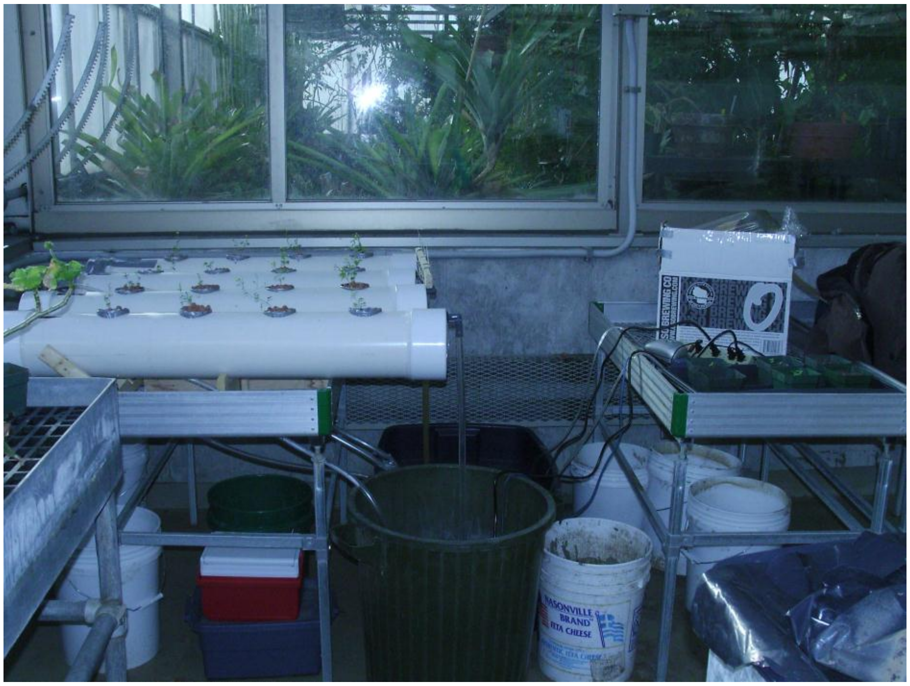


Figure 5. Week 1 hydroponic system.

Figure 6. Netpod filled with Hydroton pellets showing roots from a plant grown in the control solution.

Figure 7. First true leaf of a control plant showing Mg deficiency during week 5. Algae colonization on the Rockwool cube.

Figure 8. Algae growing in the outlet hose of a tube A.

Appendix C Works Cited

Carballo, T., Gil, M.V., Calvo, L.F., Moran, A.. 2009. The influence of aeration system, temperature and compost origin on the phytotoxicity of compost tea. Compost Science and Utilization. **17(2):** 127-139.

Hopkins, W.G. 1999. Introduction to plant physiology. John Wiley & Sons, Inc., Toronto.

Ingham, E. 2002. The Compost Tea Brewing Manual. Soil Foodweb Inc.. Corvallis, OR.

Jones Jr., J.B. 2005. Hydroponics: A practical guide for the soilless grower. CRC Press. New York, NY.

Luedtke, B. 2009. Use of compost tea as a nutrient amendment for plant growth in a re-circulating hydroponic system. UW-System Solid Waste Research Program 2009-2010 Fiscal Year Student Research Grant. Funded 21 November 2009.

Morris, D., Freeland, J., Hinchliffe, S., Smith, S.. 2003. Changing Environments. The Open University. Milton Keynes, UK.

Pant, A.P. 2009. Vermicompost extracts influence growth, mineral nutrients, phytonutrients and antioxidant activityin pak choi (*Brassica rapa* cv. Bonsai, Chinesis group) grown under vermicompost and chemical fertilizer. Journal of Science and Food Agriculture. **89:** 2383-2392.

Plant-Prod. 2001. Water soluble fertilizers: Fertilizer guide for horticulture and agriculture. Plant Products Co. Ltd., Brampton, Ontario.

Purvis, P., Chong, C., Lumis, G.. 1999. Recirculation of nutrients in container nursery production. Can. J. Plant Sci. **80:** 39-45.

Scheuerell, S. and Mahaffee, W. 2004. Compost tea as a container medium drench for suppressing seedling damping-off caused by *Pythium ultimum*. The American Phytopathology Society. **94:** 1156-1163.

Welke, S. 2005. The effect of compost extract on the yield of strawberries and the severity of *Botrytis cinerea*. Journal of Sustainable Agriculture. **25(1):** 57-68.