Lowering the Cost of Aeroponic & Hydroponic Urban Farming with Compost Tea

2014 Final Report

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Summary

A greenhouse study was conducted to evaluate the potential for use of compost tea to lower the input cost for producing vegetables. In each of nine trials conducted during 2012 through 2014, plants fertilized with daily doses of compost tea appeared to be healthier than the controls fertilized with just water, but grew slightly slower than those fertilized with store bought solutions at recommended rates. This is what was expected, however as the goal is to determine if we could utilize compost as a means of fertilizer on a regular basis, we needed to analyze the growth of the plants over time observing both the quality of the plants and the nutrient content. The trial consisted of utilizing 4 store-purchased nutrients, 4 compost-tea based nutrients, and water from an aquaponic system with tilapia.

In the trial conducted during the summer of 2013, yield of leafy greens and tomatoes showed a significant difference for different treatments. The plants fertilized with store-bought nutrients produced a healthier plant with larger leaf size when compared to the plants treated with just the compost tea solutions. However the aquaponic fish water, although not as nutrient rich in the beginning, produced similar results to those produced from store-bought solutions. The major difference was the cost: water from the aquaponic system produced the results we were looking for at around the right cost. This leads us to believe that an aquaponic system that is in complete equilibrium will produce a plant as healthy as plants fertilized with store-bought hydroponic nutrient fertilizer but at a far less cost. We

believe an aquaponic system may prove useful to organic vegetable growers.

Introduction

Compost tea (CT) was first introduced to me by Will Allen of Growing Power Milwaukee during a talk in Kansas City. Will stated that 300 lbs. of food waste compost would produce 1500 gallons of compost tea that can be used within our aeroponic/hydroponic systems. We enlisted several students from local charter schools and St. Louis public schools to help in order to expose them to learning about how to make not only compost tea, but also how to study growth of plants in whole. Many of them had been growing vegetables in school gardens but few actually performed tests on what they grew or had an understanding of what compost tea actually was.

A number of urban farmers have been using compost tea for foliar applications but an increasing body of experimental evidence indicates that plant production can be improved by using a variety of compost preparations (Scheuerell and Mahaffee, 2002). Compost teas, are prepared using various processes, which could include brewers and added ingredients such as including bacteria, fungi, protozoa and nematodes (Ingham, 2002). Compost teas are an inexpensive way to provide nutrients to plants based on composted materials being brewed for several hours and then adding them to your soil or as a foliar application. Our methods of making compost teas are strictly for application within an aeroponic hydroponic tower garden system. Our goal is to lower the cost of producing a liquid fertilizer compared to our current process of purchasing store-bought brands. It is imperative that we use high quality compost as store-purchased liquid fertilizer solutions for hydroponics all have concentrated NPK levels and have shown proven results for growers in the past.

Compost being the source of organic matter and organisms for extraction means the quality is very important! Often individuals will make compost tea from just worm castings alone or blended with compost because of their highly diverse microbial composition. Although there are supplemental nutrients (like Compost Tea Catalyst™) available to add to the tank at the beginning of the brewing process (to encourage the growth and proliferation of diverse aerobic microorganisms beneficial to plant growth), we will not be using such additives. We chose this route due to our belief that this test should focus on providing the lowest cost solution for the highest quality tea, and purchasing a supplement will result in increasing our input costs.

Our experiments were conducted in a greenhouse or an indoor controlled environment in order to maintain consistency between our controls and experiments. Experiments are focused solely on root application, and the use of various tea recipes in order to test our hypotheses and the quality of compost.

Objectives/Performance Targets

A short-term outcome of this project will be enhanced knowledge by cooperating farmers and researchers about compost and compost tea quality, related to costs for aeroponic/hydroponic vegetable production, particularly leafy greens and tomatoes. Intermediate outcomes would include determining the realities of producing a commercially viable compost tea that can be produced at a low cost and made available to local urban farmers or hydroponic farming facilities. We look to produce results that would support organic and conventional growers for improved vegetable crop health. Intermediate outcomes may also include continued research or implementation studies on the use of compost tea compared to aquaponic farming to improve vegetable crop health. The long term outcome and goal are to successfully share the information found in this compost tea research project and provide an alternative solution to the high cost of liquid fertilizers used in agricultural farming operations located within urban environments. This could include adoption of certain methods for using compost and compost tea on a more widespread basis, leading to improved quality and yields of vegetable crops for hydroponic farmers, and the reduction in the use of synthetic fertilizers by hydroponic growers. If successful this could:

a) improve the profitability of urban hydroponic producers and

b) improve the environmental quality and natural resources base on which agriculture depends through reduction in synthetic nutrient use and waste plastic buildup from nutrient solution containers.

Materials and Methods

St. Louis – summer 2012 Beginning Experiment. Our study was conducted to evaluate the potential of compost tea, applied through drip fertigation methods in a total of 8 aeroponic systems, to replace store purchased nutrient solutions. Applications of solutions were randomized in a multi-plot experiment with three factors: zero-plant application of Nutrients for control; fertigation with 1 of 8 nutrient solutions comprised of the following.

- Store Bought Nutrient Solution 1: Organicare Solution A & B
- Store Bought Nutrient Solution 2: Flora Nova Solution A & B
- Store Bought Nutrient Solution 3: Cyco Grow Solution A & B
- Store Bought Nutrient Solution 4: Boost Grow Solution A & B

- Compost Tea 1: Compost solids makeup: Coffee grounds, hops, etc.
- Compost Tea 2: Compost solids makeup: Food waste, vegetable and fruit waste materials
- Compost Tea 3: Compost solids makeup: Bat/ Sea Bird Guano, Seaweed extract, Food waste,
- Compost Tea 4: Compost solids makeup: All 1-3 combined

Fertigation treatments were main plots with zero fertilizer as sub-plots and the foliar sprays as sub-subplots. The trial was replicated four times and was conducted in collaboration with 3 separate schools as well as students from the St. Louis Science Center's Youth Exploring Science Program.

The trials were conducted in 8 aeroponic tower systems. This allowed us to test multiple plants within each system in addition to observing the root health by being allowed to remove the entire plant within the system exposing the roots. The systems maintained a reservoir with submersible pump at the base of the system, which allowed the continued feeding of plants through a recirculating process. The systems were set to timers that allowed feeding to take place at the same time each day to prevent having any potential results that could affect our data. Individual systems consisted of 10 plants with 6 inch spacing between plants. A 3:2:4 fertilizer was chosen as the standard measure of NPK for use and was applied at a rate of 1 cup per 25 gallons of water. The same ratio was used for the concentrated compost tea mix.

Seeds of ‘Deer Tongue’ Bibb Lettuce, ‘Ruby Red’ Swiss Chard, and a Cherry Tomato cultivar were sown on April 15th in flats with rock wool as the medium and plants were watered as needed.

Plots were irrigated twice a week and fertigated with compost tea or calcium nitrate once a week or more often as needed throughout the summer.

The compost tea recipes consisted of the following.

Compost Tea 1:

Fifty gallons (189 L) of were brewed weekly using the following recipe: 10.0 kg (22 lb.) vermicompost, 480 mL (2 cups) unsulfured molasses, 10 lbs. Coffee grounds. Brewing time was 24 hours with vigorous aeration.

Compost Tea 2:

Fifty gallons (189 L) of CT were brewed weekly using the following recipe: 10.0 kg (22 lb.) composted food waste, 480 mL (2 cups) unsulfured molasses. Brewing time was 24 hours with vigorous aeration.

Compost Tea 3:

Fifty gallons (189 L) of CT were brewed weekly using the following recipe: 10.0 kg (22 lb.) food waste, 480 mL (2 cups) unsulfured molasses, 946.4 mL or 32 ounces of Bat Guano, 946.4 mL or 32 ounces of seaweed extract. Brewing time was 24 hours with vigorous aeration.

Compost Tea 4: All 3 combined

Fifty gallons (189 L) of CT were brewed weekly using the following recipe: 10.0 kg (22 lb.) food waste, 10 kg Coffee grounds, 480 mL (2 cups) unsulfured molasses, 946.4 mL or 32 ounces of Bat Guano, 946.4 mL or 32 ounces of seaweed extract. Brewing time was 24 hours with vigorous aeration.

The compost was kept fully aerobic, and temperatures between 135 F and 155 F were maintained for 24 hrs; the likelihood of human pathogens in the compost is nil.

The compost tea was filtered through 2 layers of nylon stocking before it was added to each of the aeroponic system reservoirs. Plots were started 2 weeks after germination (June 4th 2012).

Leaf growth was recorded weekly (May 30th to August 28th) on individual leaflet and whole plot basis.

Two leaflets were selected randomly from lower leaves on opposite sides of each plant and were marked with tags and sent to the lab.

RATING OF PLANTS

The plants were rated on two factors brix score and essential elements testing:

BRIX SCORE: as an indicator of vegetable quality was done on a weekly basis and performed within a controlled environment using a refractometer.

The quality of produce taste can be measured by obtaining the amount of soluble solids present in the plant. This method has gained popular attention and is widely used for measuring the quality of a plant.

ESSENTIAL ELEMENTS LAB TESTING

The second factor was based on lab testing results for essential elements from Kansas State University in Manhattan, Kansas.

Plants require light, water, minerals, oxygen, carbon dioxide, and a suitable temperature to grow. These absolute growth requirements must be available within appropriate ranges and in balance with others for optimum growth to occur.

A total of 17 elements are known to be required for plants to grow and reproduce normally. The elements are carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), boron (B), manganese (Mn), copper (Cu), zinc (Zn), molybdenum (Mo), chlorine (Cl) and nickel (Ni).

Vegetable plants exhibit deficiency symptoms that are characteristic for each element, and are therefore useful for diagnostic purposes. However, in many cases, the symptoms may be masked by symptoms of other nutritional disorders, those caused by unfavorable environment, or stress caused by plant pests. In these situations, plant tissue analysis provides useful information to complement and confirm visual diagnosis.

BRIX SCORING

Qualities of individual plants were rated as poor Average Good and Excellent for measuring the Brix Score. The final results for our research were as follows for Brix Score.

DEER TONGUE BIBB LETTUCE

Experiment	Poor	Average	Good	Excellent
Solution I				8
Solution II				8
Solution III				9
Solution IV				7
Tea 1	4			
Tea 2		5		
Tea 3			6	
Tea 4				7.2
Aquaponic Water				6.8

SWISS CHARD

Crop	Poor	Average	Good	Excellent
Solution I		6.0		8
Solution II		5.8		8
Solution III		5.7		9
Solution IV		6.3		7
Tea 1	3			
Tea 2		5.7		
Tea 3		6.0		
Tea 4		6.2		
Aquaponic Water				6.2

CHERRY TOMATO

Experiment	Poor	Average	Good	Excellent
Solution I				8
Solution II			7	
Solution III				8
Solution IV			7	
Tea 1	4			
Tea 2		5		
Tea 3			6	
Tea 4				8
Aquaponic Water				7.2

Critical (deficiency) values, adequate ranges, high values, and toxicity values for macronutrients for vegetables (most-recently-matured whole leaf plus petiole (MRM leaf) unless otherwise noted).

CROP	**PLANT PART**	**TIME OF Sampling**	**Status**	**%**					
				N	P	K	Ca	Mg	S
TOMATO	MRM leaf	5 leaf stage	Deficient	<3.0	0.3	3.0	1.0	0.3	0.3
			Adequate	3.0	0.3	3.0	1.0	0.3	0.3
			Range	5.0	0.6	5.0	2.0	0.5	0.8
			High	>5.0	0.6	5.0	2.0	0.5	0.8
	MRM leaf	First Flower	Deficient	<2.8	0.2	2.5	1.0	0.3	0.3
			Adequate	2.8	0.2	2.5	1.0	0.3	0.3
			Range	4.0	0.4	4.0	2.0	0.5	0.8
			High	>4.0	0.4	4.0	2.0	0.5	0.8
	MRM leaf	Early Fruit Set	Deficient	<2.0	0.2	2.5	1.0	0.3	0.3
			Adequate	2.5	0.2	2.5	1.0	0.3	0.3
			Range	4.0	0.4	4.0	2.0	0.5	0.6
			High	>4.0	0.4	4.0	2.0	0.5	0.6
	MRM leaf	First Ripe Fruit	Deficient	<2.0	0.2	2.0	1.0	0.3	0.3
			Adequate	2.0	0.2	2.0	1.0	0.3	0.3
			Range	3.5	0.4	4.0	2.0	0.5	0.6
			High	>3.5	0.4	4.0	2.0	0.5	0.6
	MRM leaf	During Harvest	Deficient	<2.0	0.2	1.5	1.0	0.3	0.3
			Adequate	2.0	0.2	1.5	1.0	0.3	0.3
			Range	3.0	0.4	2.5	2.0	0.5	0.6
			High	>3.0	0.4	2.5	2.0	0.5	0.6

CROP	PLANT PART	TIME OF Sampling	Status	Ppm					
				Fe	Mn	Zn	B	Cu	Mo
Lettuce	MRM leaf	8 leaf stage	Deficient	<50	20	25	15	5	-
			Adequate	50	20	25	15	5	-
			Range	150	40	50	30	10	-
			High	>150	40	50	30	10	-
	Wrapper leaf	Heads 1/2 size	Deficient	<50	20	25	15	5	-
			Adequate	50	20	25	15	5	-
			Range	150	40	50	30	10	-
			High	>150	40	50	30	10	-
	Wrapper leaf	Maturity	Deficient	<50	20	25	15	5	-
			Adequate	50	20	25	15	5	-
			Range	150	40	50	30	10	-
			High	>150	40	50	30	10	-

CROP	PLANT PART	TIME OF Sampling	Status	Ppm					
				Fe	Mn	Zn	B	Cu	Mo
Swiss Chard	Leaf blades	5 weeks after seeding	Deficient	<40	30	15	30	5	0.05
			Adequate	40	30	15	30	5	0.2
			Range	200	200	30	80	10	0.6
			High	-	-	-	80	10	-
	MRM leaf	9 weeks after seeding	Deficient	-	-	15	30	5	0.1
			Adequate	-	70	15	60	5	0.6
			Range	-	200	30	80	10	-
			High	-	-	-	80	10	-

CHERRY TOMATO

Experiment	N	P	K	Ca	Mg	S
Solution I	4.8	0.6	4.6	2.0	0.5	0.4
Solution II	5.0	0.6	4.8	1.8	0.5	0.3
Solution III	4.7	0.6	4.5	2.0	0.5	0.4
Solution IV	5.0	0.6	5.0	2.0	0.5	0.4
Tea 1	3.0	0.3	3.8	1.0	0.2	0.2
Tea 2	4.2	0.6	4.5	1.8	0.3	0.3
Tea 3	4.8	0.5	4.5	1.6	0.3	0.3
Tea 4	4.8	0.6	5.0	2.0	0.4	0.3
Aquaponic Water	5.0	0.5	4.5	1.8	0.4	0.3

Note: Cherry tomato data displayed above was measured at harvesting stage

SWISS CHARD

Experiment	Fe	Mn	Zn	B	Cu	Mo
Solution I	-	117	20	64	5	0.5
Solution II		128	24	50	5	0.4
Solution III		150	22	34	7	0.6
Solution IV		150	28	68	6	0.6
Tea 1	-	-	14	20	2	-
Tea 2		97	21	44	2	
Tea 3		119	22	20	5	
Tea 4		128	25	7.2	4	
Aquaponic Water		138	24	50	4	-

Note: Swiss chard data displayed above was measured 9 weeks after seeding

DEER TONGUE LETTUCE

Experiment	Fe	Mn	Zn	B	Cu	Mo
Solution I	-	117	20	64	5	0.5
Solution II		128	24	50	5	0.4
Solution III		150	22	34	7	0.6
Solution IV		150	28	68	6	0.6
Tea 1	-	-	14	20	2	-
Tea 2		97	21	44	2	
Tea 3		119	22	20	5	
Tea 4		128	25	7.2	4	
Aquaponic Water		138	24	50	4	-

Note: Lettuce data displayed above was measured at maturity stage

Results and Discussion/Milestones

As expected, the store-purchased nutrients solutions **I-IV** out performed compost tea solutions **1-3**. However compost **Tea 4** came the closest to store purchased solutions **I-IV**. Plants grown with Tea 4 showed similar data as well as similar Brix scoring and Essential Elements testing through plant tissue lab testing. The one caveat is that the cost of purchasing the compost additives such as Bat Guano Seaweed extract was similar to the cost of store-purchased nutrient solutions **I-IV**. As a result Compost Tea 2 provided a better performance compared to price. Overall the aquaponic system provided the best results in the end, but performed poorly in the initial testing due to the system not having enough bacteria to provide enough nutrients to the plants. Over time the system began to produce promising results. Although the cost of building an aquaponic system would surely cost more than purchasing solutions, in the long run the system will provide the lowest input cost over time since the fish are producing the nutrients needed. On occasion purchasing Calcium and magnesium and other nutrients for the aquaponic grow beds would supplement any nutrient deficiencies that would occur and eventually the system's water would provide nutrient rich water for plants. Our research has shown that it would take about 6-7 months for the aquaponic system to function properly with a total of 50 fish in a 300 gallon tank with grow beds made of 3/4" clean rock. Fish can be fed with duckweed or black soldier fly larvae to keep the feed input costs low. We would have to perform more tests to analyze this in greater detail to provide any real data.

Impact of Results/Outcomes

The work done under this project was primarily conducted on aeroponic tower systems in a controlled building and greenhouse environment. There was a great impact from our collaboration with the St. Louis Public Schools and students from the Science Center's Youth Exploring Science program. We could have provided more detail on the compost makeup as well as . Grower cooperators established school plots for assessing effects of compost tea on their plants and began to develop their own experiments during 2013. The results of the experiments that we conducted indicate that compost tea may have the potential to be used in hydroponic and aeroponic systems, and in some cases can compete with store-purchased nutrient solutions when combined with additives and supplemental products to provide additional nutrients and minerals not present in most compost teas. In our trials we were looking at not only plant performance but the costs associated with achieving the desired performance as well. Because of this we believe that utilizing aquaponic fish water would provide the most cost benefit in the long run. Our results will need to be further evaluated at the farm level to determine the potential of compost tea as a nutrient solution in hydroponic and aeroponic farming applications. We achieved consistent results over 4 trials, that compost tea needs to be supplemented and provides a strong justification for further evaluation of compost tea in additional farm production systems.

Economic Analysis

Assuming that compost tea is as efficacious as nutrient applications (this requires further study), and that quality of the plants can match store-purchased solutions with supplemental products, the main costs to using compost compared to store-purchased nutrients would be the labor and additional products that would need to be purchased to achieve the same results. In addition the cost of a brewer is $350, which could be covered over several seasons. If making bulk purchases of compost tea ingredients, the cost of ingredients to make 50 gallons of tea would be $0.8. The cost of the brewer is spread over 60 applications (12/season for 5 seasons). The same can be said for a 300-gallon tank aquaponic system built for the same price including fish. This compares with the cost of the nutrients, which range in price from $118 for 5 gallons that would last 6 months compared to not having to purchase them at all because they are produced by the fish.

Publications/Outreach

Our results of this work have been presented to various visitors that arrive at the Science Center's Taylor Community Science Resource Center located in South St. Louis City. The center hosts 300 students from the Youth Exploring Science Center program and provides the students with hands-on STEM learning through applied project-based learning. This was a perfect place to showcase the experiment and trials and has peaked interest in students from over 30 schools. This was first presented in summer of 2013 and the aeroponic tower systems were on display in the lobby of the building. Students were encouraged to develop their own nutrient solutions and experiment with the aeroponic systems. This began on May 15, 2013 and is still on display.

In addition we provide a luncheon and showcased our research to Science Center Staff and visitors and students that included 300 students, 30+ adults and educators from various public schools and local community organizations.

Farmer Adoption

More research needs to be conducted before approaching hydroponic farmers for adoption of compost tea for nutrient solutions. Currently students are researching ways to use compost tea in combination with aquaponic fish water for nutrient solutions.

Participants:

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- Dobbie Herrion - Research assistant
- Kerri Stevinson - Agriscience Educator - Saint Louis Science Center
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