Report as of FY2008 for 2007VI90B: "Response to Uncertain Irrigation Supplies Through Recovery and Application of Aquaculture Wastewater for Agronomic Crops Cultivated in the U.S. Virgin Islands"

Publications

- Articles in Refereed Scientific Journals:
    - Danaher, J. 2008. Evaluating Geotextile Technology to Enhance Sustainability of Agricultural Systems in the US Virgin Islands. Aquaponics Journal, Issue #50 (3rd Quarter), Pages 18-20.
- Other Publications:
    - Danaher, J. 2008. Maximizing available freshwater resources through integrated farming practices in the U.S. Virgin Islands. Agrifest 2008 The business of agriculture: The way forward . 37th Annual Agriculture and Food Fair of the U.S. Virgin Islands. February 16 -18, St. Croix, U.S. Virgin Islands.
    - Danaher, J.J., J.E. Rakocy, D.S. Bailey, R.C. Shultz, and K. Lincoln. 2008. Use of a Geotube® for recovery of aquaculture wastewater for agronomic crops cultivated in the U.S. Virgin Islands. Aquaculture America 2008, Disney s Coronado Springs Resort, Lake Buena Vista, Florida, USA, February 9-12.
    - Danaher, J.J., J.E. Rakocy, R.C. Shultz, and D.S. Bailey. 2009. Reclaimed aquaculture effluent for use on cucumbers Cucumis sativus cv Eureka grown in the U.S. Virgin Islands. Aquaculture America 2009, Seattle, Washington, USA, February 15 -18.

Report Follows

PROBLEM AND RESEARCH OBJECTIVES

Improving water use efficiency is critical to most Caribbean islands where there is low per capita freshwater availability. Concerns for water conservation in the U.S. Virgin Islands have promoted the development of intensive, recirculating fish production systems. These systems treat and reuse a major portion of their production water, but rely on the removal of nutrients and organic matter through biological and mechanical processes to ensure system sustainability. Discharged aquaculture effluent is comprised of organic matter and high levels of nitrogen and phosphorus which can pose an environmental threat; thus increasing waste production through intensification will require novel methods for managing aquaculture effluent. To abate the environmental impact new management practices need to be adopted to reuse the nutrients and water. Integrating recirculating aquaculture systems with the production of other valuable agronomic crops to recycle nutrients and reuse water could provide a viable solution to sustainable food production in semi-arid regions. Experiments have demonstrated aquaculture effluent to be an excellent nutrient source for agronomic plants; thus, effluents should be treated as a resource management and not as a disposal problem. One major constraint to the integration process has been clogging of irrigation systems due to high levels of organic matter. Technology that is capable of separating the solid fraction from the liquid portion of fish effluent would give farmers increased options for integrating aquaculture and vegetable production.

Geotube technology now exists and creates a more flexible approach for the integration of aquaculture effluent with agronomic crops. A Geotube is constructed from a high strength woven geotextile fabric that can be filled repeatedly with aquaculture effluent and allowed to dewater for a period of time. This process could possibly create options and opportunity for the agricultural operator by allowing the solid fraction retained in the Geotube to be used as a fertilizer and the filtrate exiting the Geotube to be used as a water source for agronomic crops.

The objectives of the project are to:

1. Evaluate geotextile material (Geotube) for the recovery and reuse of solids, wastewater, and dissolved nutrients from aquaculture effluent for use on agronomic crops.
2. Evaluate the efficacy of drip irrigation systems delivery of Geotube filtrate.
3. Evaluate the nutrient content of Geotube retained solids, establish its quality for amending soils in agronomic crop plots, and establish if the filtrate is a nutrient source based on plant response.

METHODOLOGY

Experiment A

Objective I and objective 2 were assessed through experiment A. A 150-m3 lined, storage pond was the source of the fish effluent. A Geotube measuring 7.6m x 2.3m was installed adjacent to the storage pond. A 3/4-Hp vertical lift aerator and horizontal mixer were used to agitate the fish effluent prior to each pumping event. A 1/3-Hp pump, pumped effluent at a rate of 114 liters/minute. Prior to entering the Geotube the effluent was treated with a polymer, Hyperfloc CE 854, (Hychem, Inc., Tampa, FL) at a concentration of 14.2 mg/L and allowed to mix by passing through a series of 90-degree PVC elbows. The first two pumping events occurred on 29 November and 14 December 2007. The final occurred on 17 January 2008. On each sampling date, three pond sludge (PS) samples were collected directly adjacent to the pump at a depth of 30 cm. A 250-mL aliquot of the samples was sent for water quality analysis of PS. On each sampling date three samples of Geotube (V filtrate (GF) were also taken from different locations where filtrate was weeping from the Geotube during filling. A 250-mL aliquot of the samples was sent for analysis of GF. A sample of retained solids (RS) in the Geotube was taken on 17 January prior to the final pumping event and analyzed for pH, organic matter, moisture content and nutrient concentrations. Water samples of PS, GF, and RS were sent to Micro Macro International, Inc. (Athens, GA) for analyses of micro- and macronutrient concentrations. Over a four-week period GF was pumped through a T-tape irrigation system to determine if clogging occurred.

Experiment B

This is an on-going project evaluating objective 3. The study is evaluating RS and GF as nutrient sources compared to a commercial inorganic, slow release fertilizer (Osmocote). The experiment consists of three treatments with three replicates (28_M2) each. The control is a slow-release 12-12-12, inorganic fertilizer [Osmocote] with rainwater. Treatment two is RS with rainwater and treatment three is RS with GF. A Randomized Block Design was used for the experimental design and data will be analyzed using ANOVA

Based on an initial soil test of the growing area a recommended fertilization application was applied. Each fertilizer was applied and rototilled in on 1 April. Osmocote was applied at the equivalent of 880 kg/ha and RS (83 % moisture) was applied at the equivalent of 5 mt/ha. Cucumber (Cucumis sativus v. Eureka) were seeded in the greenhouse 8 April. On April 21s' a Geotube was filled and filtrate was collected for irrigation purposes. A sample of the filtrate and rainwater was sent for nutrient analysis. A T-tape'v irrigation system was installed to deliver water. On 21 April a soil test was performed at the beginning of the experiment and another will be performed at the end of the experiment to compare soil pH, buffer pH, N03-Nitrogen, Ca, Mg, K, P, B, Cu, Fe, Mn, Na, S, Zn, organic matter, calculated cation exchange capacity (CEC), and base saturation %. Transplants were planted on the 22 April. Spacing between rows is 0.37 m and plant spacing within each row is 0. 1 9 in. Straw mulch was added on 25 April.

PRINCIPAL FINDINGS AND SIGNIFICANCE

Experiment A

Table 1. Averages of water quality parameters and nutrient concentrations measured during experiment for pond sludge (PS), geotube filtrate (GF), and geotube retained solids (RS)

	Pond Sludge Mean±S.D.	Geotube Filtrate Mean ± S.D.	Percent Removal	Geotube Solids
!pH	7.6 ± 0.3	7.7 ± 0.4		8.1
Temperature	24.5 ± 0.5	24.5 ± 0.5		
Alkalinity (mg/L)	860.0± 34.6	801.3 ± 90.5		
TSS (mg/L)	22,525.0 ± 3,892.2	115.0 ± 68.7	99	
Macronutrients (mg/I.)				
NPK(%)	0.09: 0.15 : 0.03	0.02 : 0.04 : 0.03		3.6 : 6.0 : 0.2
Total Nitrogen	89ft 7 ± 27.3	244.5 ± 59.7	73	36,400.0
Phosphorus	670.3 ± 550.1	155.7 ± 207.5	77	60,026.0
Potassium	248.4 ± 151.1	225.8 ± 151.3	9	1,852.0
Calcium	3,404.5 ± 2,878.4	417.3 ± 333.4	88	136,242.0
Magnesium	127.D±62.J	66.3 ± 69.4	48	2,447.0
Micronutrients (mg/L)				
Iron	33.3 ± 14.1	14.5 ± 19.9	56	2,028.0
Copper	8.0± 7.0	8.3 ± 10.5	-4	112.0
Zinc	23.8 ±22.0	22.3 ± 15.9	6	1,195.0
Boron	5.5 ± 3.7	13.5 ± 19.1	- 73	48.0
Manganese	13.0± 9.0	5.8 ± 10.8	55	773.0
Molybdenum	7.3 ± 9.0	13.3 ± 20.0	- 82	0.0

Results are presented in Table 1. The geotextile bag reduced TSS concentration 99%. The T - tape® drip irrigation system did not clog using GF. All macronutrient concentrations decreased, while micronutrient concentrations were found to either increase or decrease in GF samples. The pH of RS was higher than the average PS or GF readings. Results found RS contained substantially higher NPK levels than either the PS or GF. Comparison of PS and RS showed the *geotextile* bag concentrated rnacronutrients and micronutrients by factors ranging from 7 - 40x and 0 - 60x, respectively. Analysis of RS showed it was composed of 59.3% organic matter with 86.4% moisture content after four weeks of dewatering.

In conclusion, the geotextile bag was highly effective in reducing the concentration *of TSS* in fish effluent. The GF contained a dilute nutrient concentration and a total of 1,230 liters of GF was shown to pass through standard, commercial irrigation systems without clogging or need for further filtration. The GF and RS from the geotextile bag would allow an integrated farming system to utilize aquaculture effluent on agronomic crops during seasonal water shortages or persistent droughts; however, the nutrient quality of the filtrate may be dependent on the source of effluent. Thus, fresh effluent exiting an established tilapia production system may have higher nutrient concentrations compared to the anaerobic effluent pond used in this experiment.

Experiment B

Results found GSGF and GSRW had significantly higher ($P < 0.05$) total number of fruits, total yield, and marketable yield compared to the Control (Table 2). There was no significant difference ($P \geq 0.05$) in the average fruit weight between treatments. There was no significant difference ($P \geq 0.05$) in plant tissue analysis between treatments (Table 3); however, plant tissue nutrient levels were below recommended ranges in all treatments. In conclusion, the low nutrient level of the filtrate provided no additive effect for cucumber production. Fresh effluent exiting an established tilapia production system may have higher nutrient concentrations compared to the anaerobic effluent pond used in this experiment and thus when dewatered may provide a better source of nutrients. Nonetheless, fish solids outperformed the inorganic fertilizer in field production of cucumber. However, it is believed cucumbers were unable to extract the slow-released nutrients from either fertilizer at the applied rate. Therefore, a second trial will be conducted with increased rates of fertilizer application.

Table 2. Average total number of fruits, total yield and marketable yield for treatments

Values followed by different letters within rows are significantly different (P less than 0.05).

	Control	GSRW	GSGF
Ave. Fruit Wt. (g)	118.7 a	131.8 a	128.8 a
Total Number of Fruits (no./ha)	16,498 b	21,017 a	21,985 a
Total Yield (kg/ha)	1,976 b	2,869 a	2,927 a
Marketable Yield (kg/ha)	1,976	2,844 a	2,905 a

Table 3. Recommended nutrient levels for plant tissue.

Values followed by different letters within columns are significantly different (P less than 0.05)

	%N	%P	%K
Control	3.1 a	0.2 a	2.2 a
GSRW	3.1 a	0.2 a	2.2 a
GSGF	3.0 a	0.2 a	2.0 a
Recommended	4.5 -6.0	0.3 - 1.3	3.9-5.5

Presentation of Findings

The findings of this research have thus far been formally presented at two workshops. The first was at an aquaculture short course for members of the St. Croix farmers cooperative and other members of the St. Croix community held during the period May 6 to June 11, 2008. This was held on the St. Croix campus of the University of the Virgin

Islands and 35 persons participated. Results were also presented at the Tenth Annual Aquaponic and Tilapia Aquaculture Short Course, June 15 – 22, 2008. Participants in the course were entrepreneurs, researchers, educators and students from all over the world. This course was also held on the St. Croix campus of UVI and 73 students participated.