Aquaponics at the College of Tropical Agriculture and Human Resources (CTAHR)

Clyde S. Tamaru, Bradley “Kai” Fox, Harry Ako, Theodore Radovich, Jari Sugano, C.N. Lee, Kathleen McGovern-Hopkins and RuthEllen Klinger-Bowen

October 8, 2011

Urban Garden Center

Who is Clyde Tamaru?

Provide technical assistance to aquaculture stakeholders.

Now includes aquaponic stakeholders.





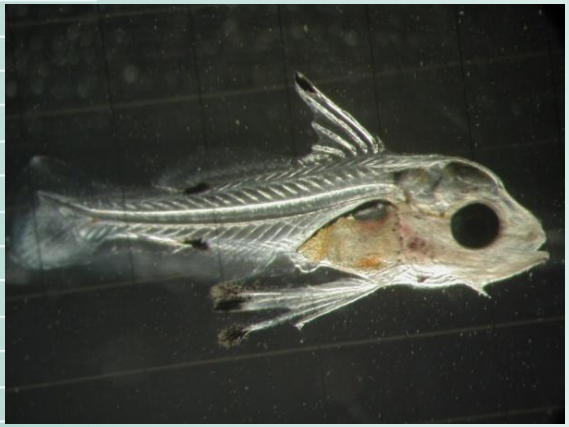

Who is Clyde Tamaru andWhy is He Here?

- McKinley High School
- B.S. Biology, @ UH Mānoa
- M.S. Zoology, @ UH Mānoa
- Ph.D. Faculty of Agriculture, Dept. of Fisheries, University of Tokyo

University of Tokyo
東京大学
1877

Who is Clyde Tamaru?

Maintains a research and extension portfolio involving three institutions.

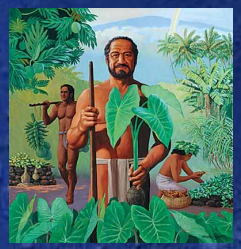
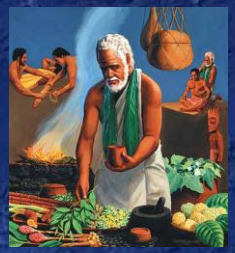
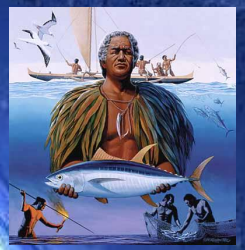
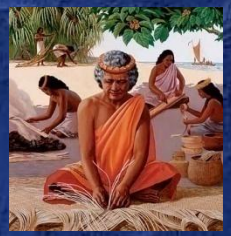


College of Tropical Agriculture and Human Resources

University of Hawai'i Windward Community College

Hawaii Institute of Marine Biology at Coconut Island

For over a thousand years ancient Hawaiians were completed isolated from the rest of the world.

Chevron

Shell

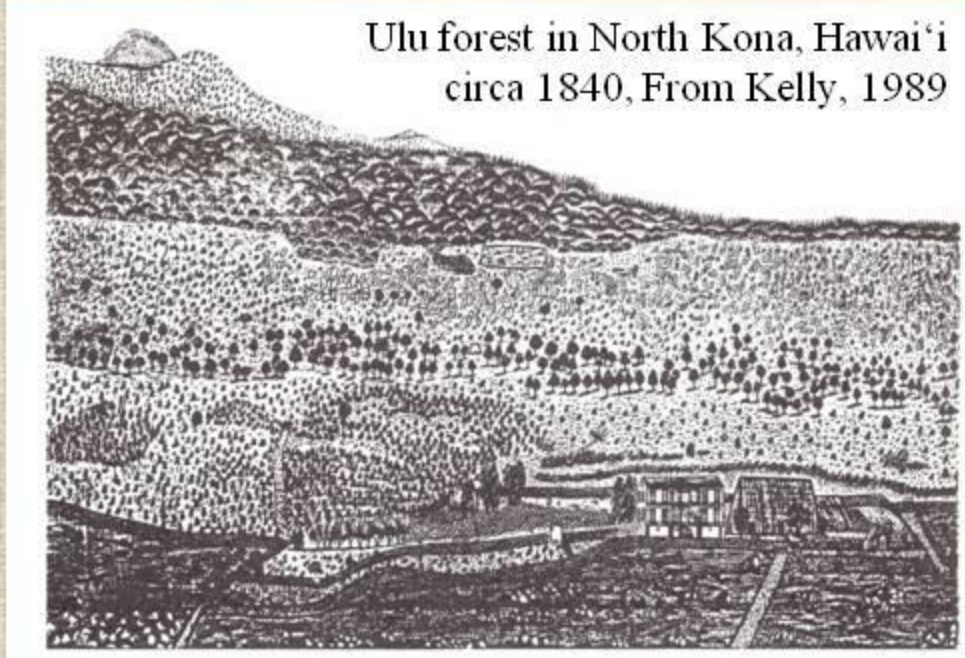
Hawaii

Currently, over 80% of our food and 90% of our energy is imported

The Ahupua‘a : A Model of Resource Management

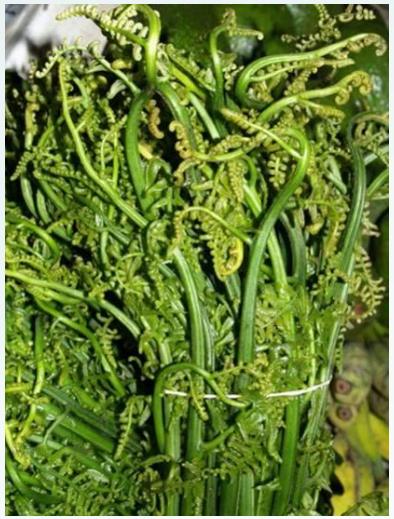
Waikalua Loko, Kaneohe Ahupua’a, 1927

Heeia Loko, Heeia Ahupua’a, 1940

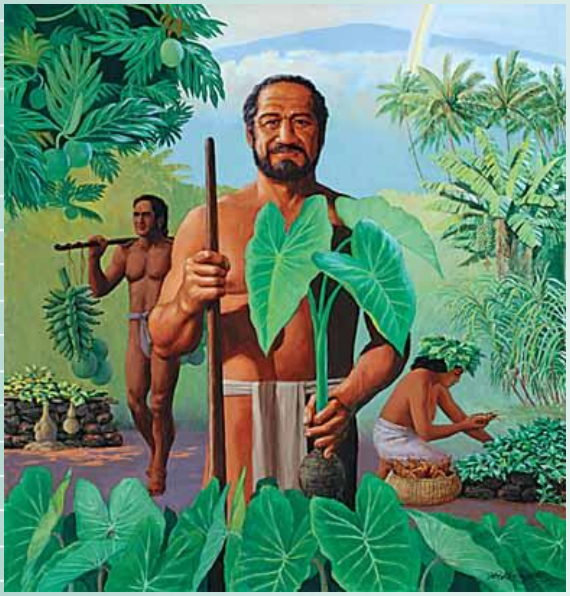


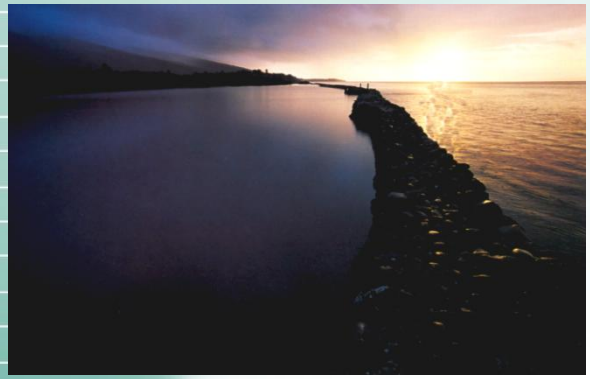
Ulu forest in North Kona, Hawai‘i circa 1840, From Kelly, 1989

LIFE IN THE AHUPUA‘A
Food Was Gathered



LIFE IN THE AHUPUA‘A
Food Was Grown

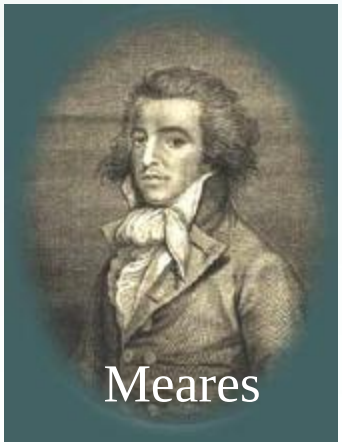




- “Some large ponds which appeared to be full of fish. He [the king] mentioned he had some others with a great quantity of turtle” - J. Meares – 1789
- “for industry of cultivation and agricultural improvements they could scarcely be exceeded in any country in the world” – Archibald Menzies - *Menzies' Journal of Vancouver's Voyage, April to October, 1792*


Vancouver


Menzies


Meares

Who are We and Why are We Here?

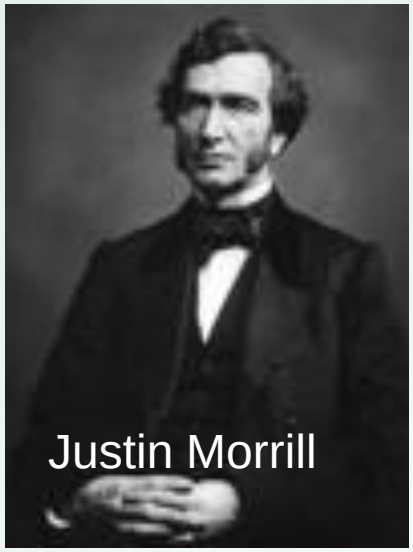
Vision: CTAHR will actively help Hawai‘i:

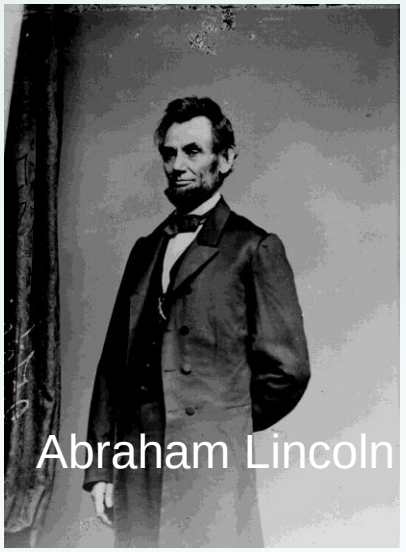
- diversify its economy
- ensure a sustainable environment
- strengthen its communities
- and will be the premier resource for tropical agricultural systems and natural resource management in the Asia-Pacific region.

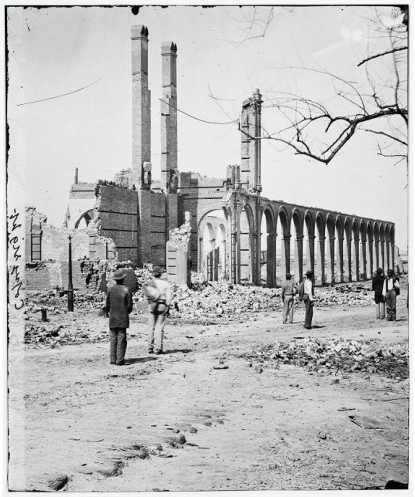
“Centennial” – white anthurium bred by UH scientists to celebrate 100th birthday

Land Grant College System

- Universities or colleges that receives the benefits of the Morill Acts of 1862 and 1890 (Education)
- Hatch Act of 1887 allowed land grant colleges to create agricultural research stations to conduct practical research that would assist farmers (Research)
- Smith-Lever Act of 1914 results in the cooperative extension services and a mechanism for technology transfer (Extension)


Justin Morrill

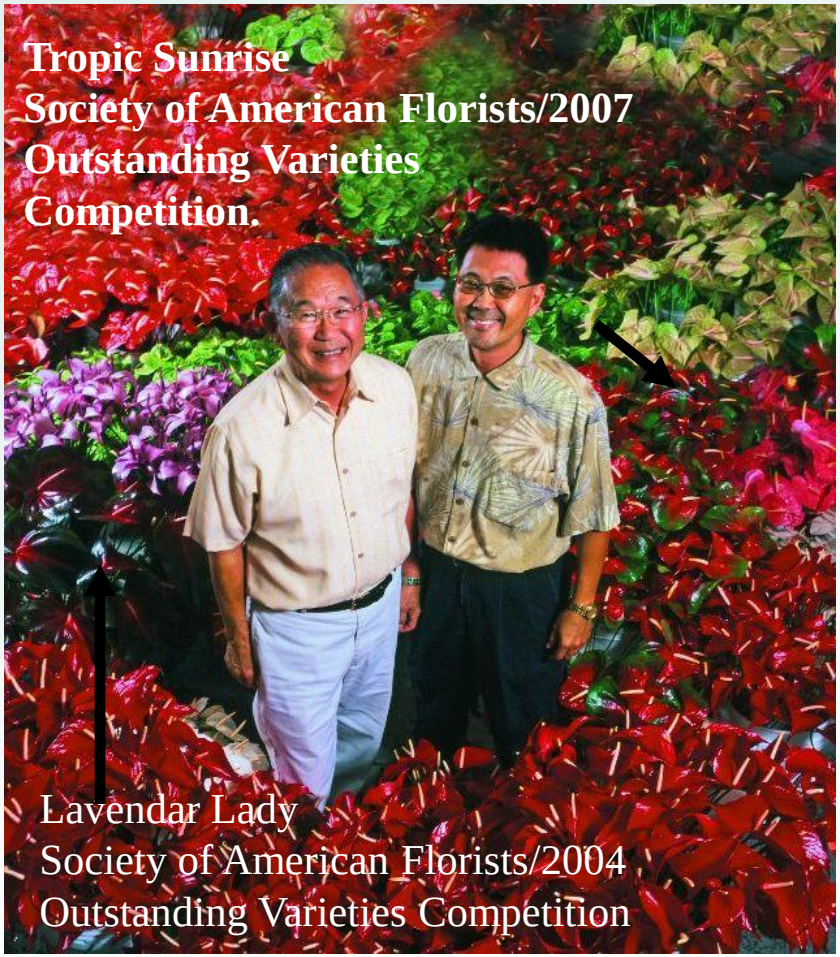

Abraham Lincoln



National Institute of Food and Agriculture

Example of How a Land Grant College Program Works

Drs. Haruyuki Kamemoto and Heidi Kuehnle with “Tropic Fire”. Helped anthuriums become the state’s most valuable cut-flower crop (farm-gate value of $4.7 million in 2005)



Harold and Eric Tanouye
Green Point Nurseries, Inc.

HAWAI'I'S Business Today
SECTION C | WEDNESDAY, APRIL 30, 2008
HONOLULUADVERTISER.COM/business

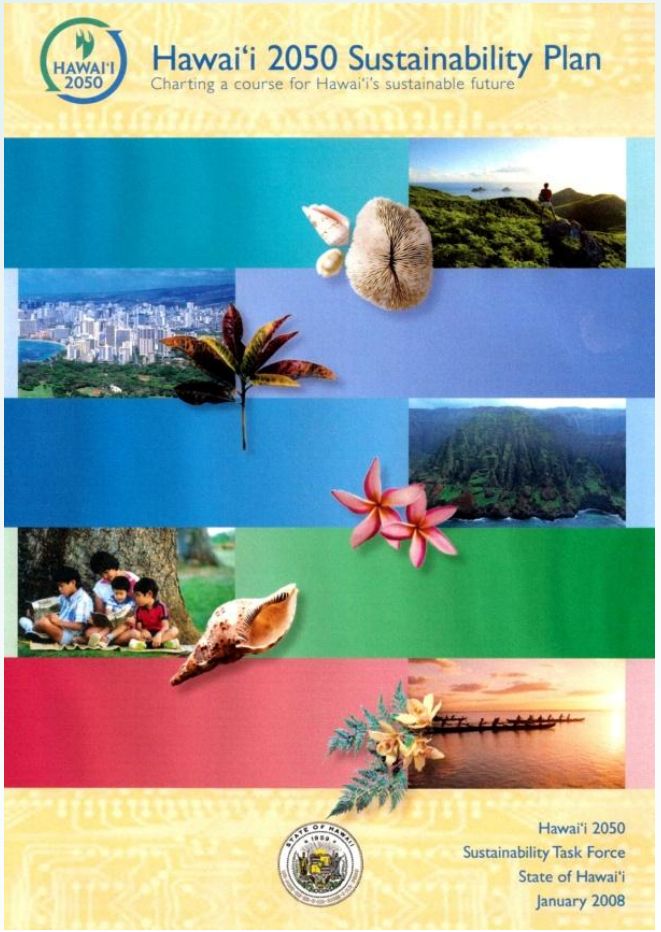
Scientists decipher papaya's genome

Research could pave way for transgenic fruit exports to Japan

An international consortium led by University of Hawaii researchers described the genetic code of the Sun Up papaya. It marks the first transgenic fruit crop to be deciphered. *Nature* **452**, 991-996 (24 April 2008)

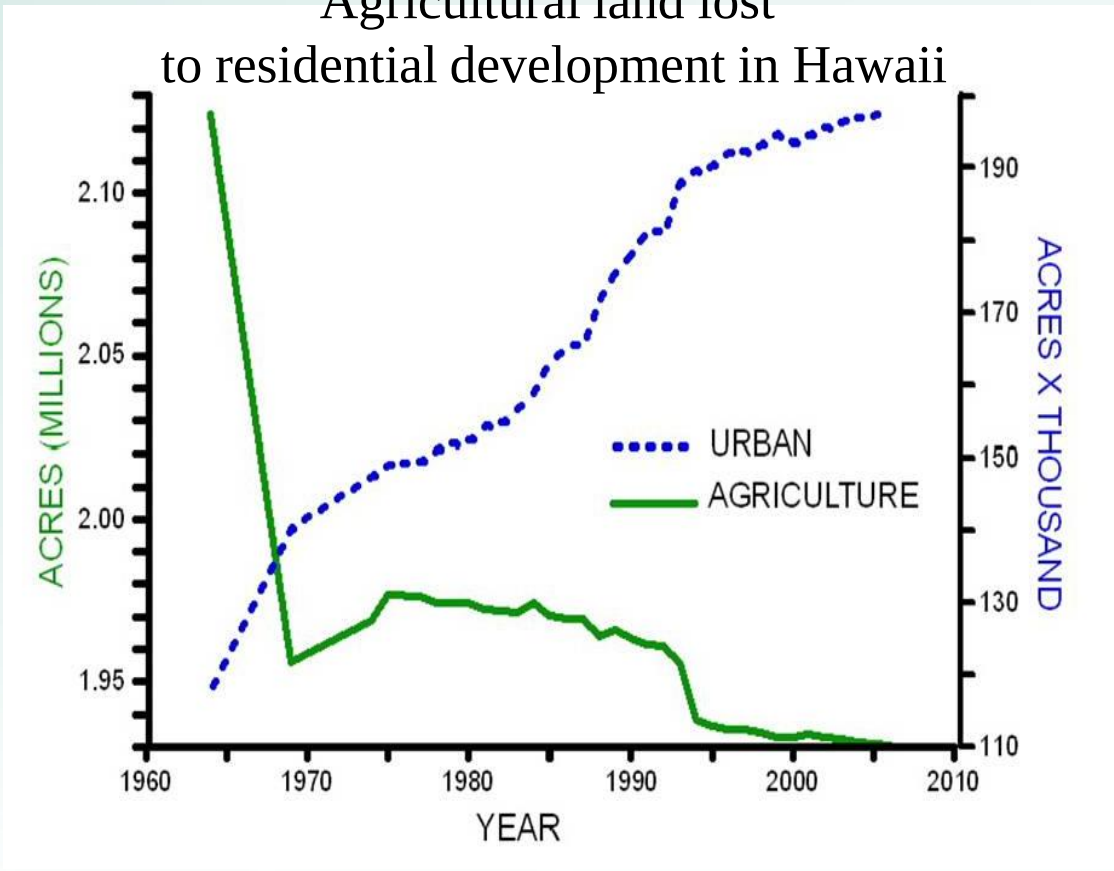
Why are we working with aquaponics?

- Addresses several priority actions outlined in Hawai‘i 2050 Sustainability Plan such as:
  - Increase recycling, reuse and waste reduction strategies.
  - Develop a more diverse and resilient economy
  - Create a sustainability ethic.
  - Increase production and consumption of local foods and products, particularly agriculture.



Justification for focusing on backyard aquaponic systems

Agricultural land lost
to residential development in Hawaii



Source: http://hawaii.gov/dbedt/info/economic/databook/Data_Book_time_series/

It is All About Expectations

My first attempt at hydroponic production of lettuce.

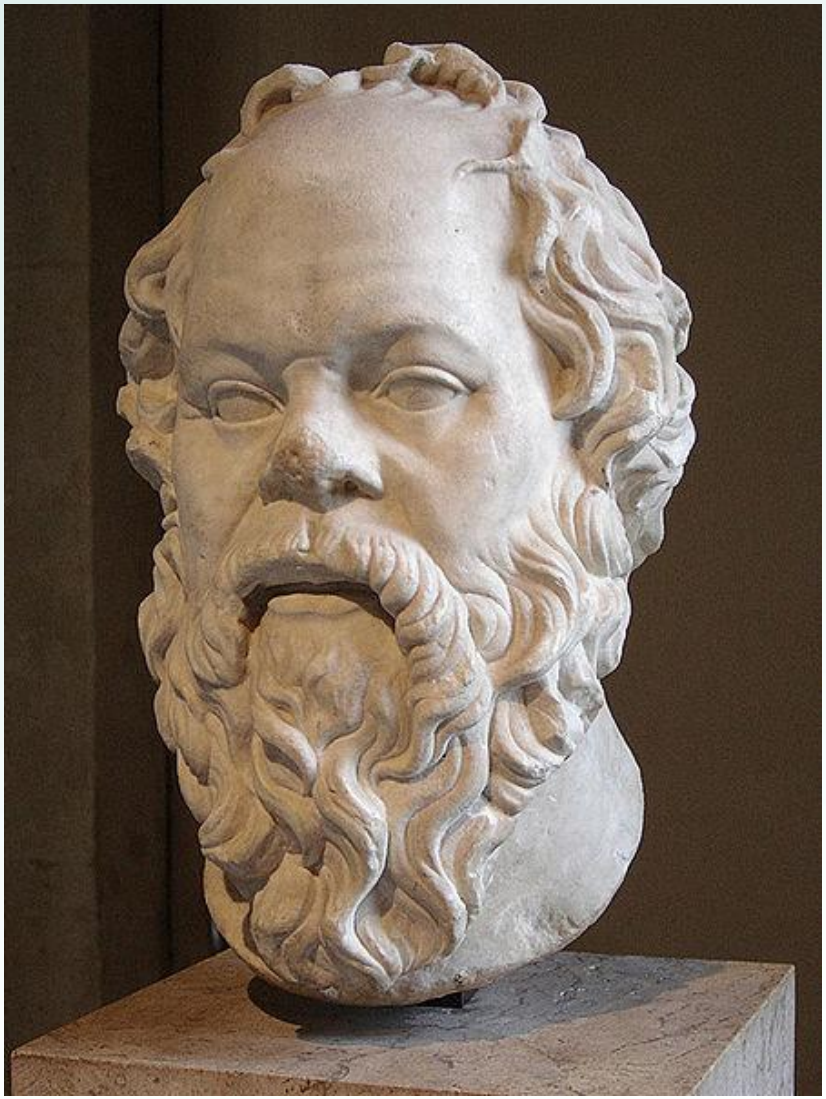
Harry Ako and Adam Baker's hydroponic production of lettuce

The Fallacy of the Artisans:

I appear to be wiser than he, because I do not fancy I know what I do not know -

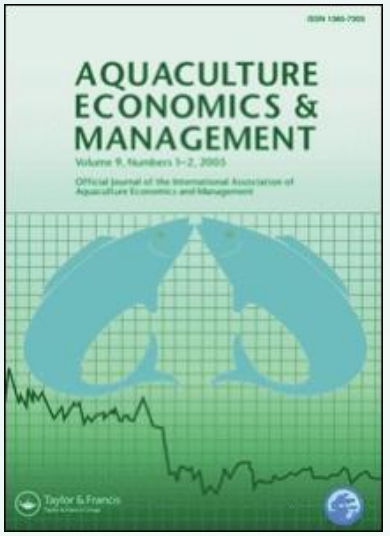
Socrates

http://www.roangelo.net/logwitt/socratic-ignorance.html



Providing the best information to make informed decisions: Are the economic benefits of integrating aquaculture and hydroponics real or perceived?

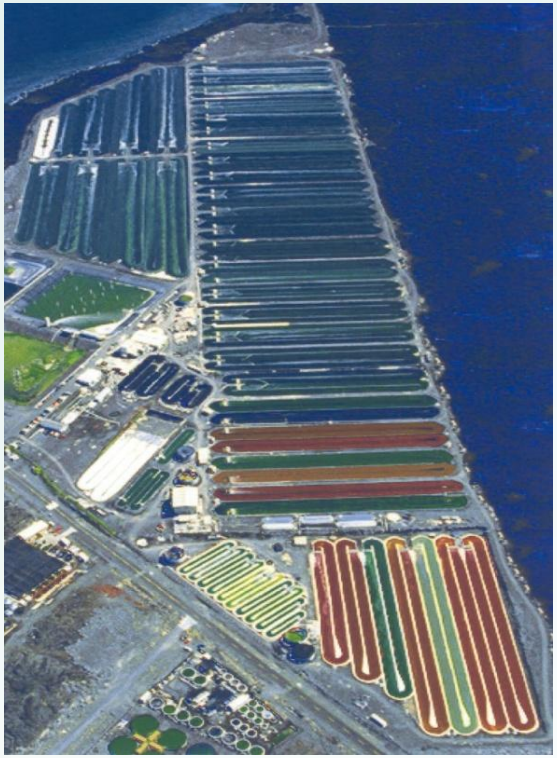
- Economic feasibility studies are few in number
- Investigation shows that Net Present Value (NPV) over a 10 year horizon is:
  - $499,000 fish alone
  - $18,397 lettuce alone
  - $522,000 integrated fish and lettuce (+ 4.6%)
- Net benefits derived from:
  - Reduction in barramundi effluent disposal costs
  - Cost savings in water
  - Cost saving in nutrients for the lettuce system.



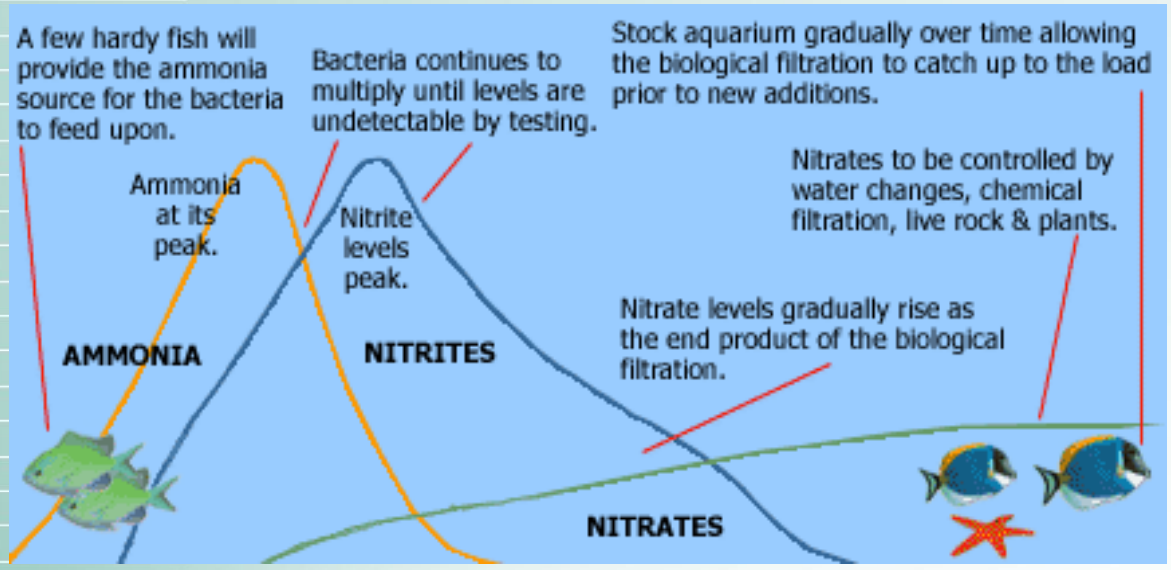
Rupasinghe and Kennedy, 2010. Economic benefits of integrating a hydroponic-lettuce system into a barramundi fish production system. Aquaculture Economics Management, 14: 2, 81-96.

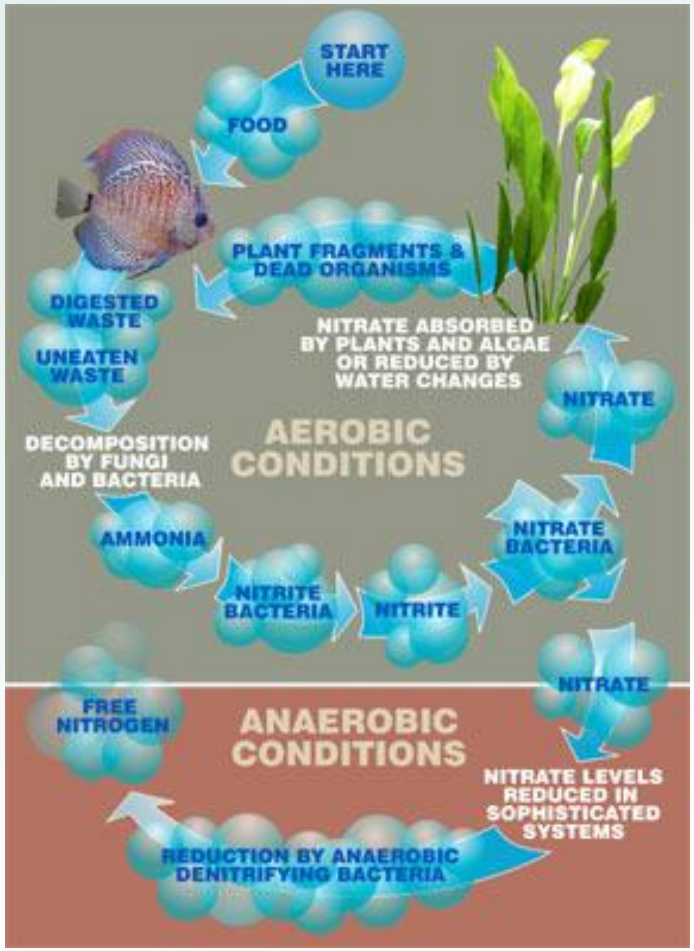
What is Aquaponics?

- Aquaculture: farming of aquatic organisms under controlled conditions.



Water Quality 101: Nitrogen Cycle in an Aquaculture Setting





Source: http://www.liveaquaria.com/PIC/article.cfm?aid=78

Chemistry of the Nitrification Process

Photo credit: Stan Watson, Woods Hole Oceanographic Institute. 2010

Nitrosomonas

$55\ NH_4^+ + 5\ CO_2 + 76\ O_2 \rightarrow C_5H_7NO_2 + 54\ NO_2^- + 52\ H_2O + 109\ H^+$

Nitrobacter

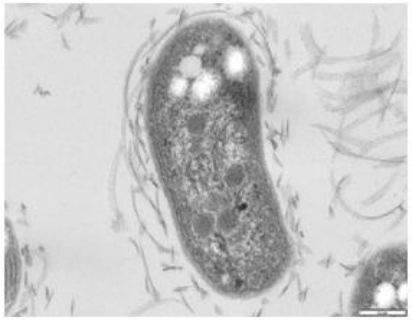


Photo credit: W.J. Hickey, University of Wisconsin-Madison, 2006

$400\ NO_2^- + 5\ CO_2 + NH_4^+ + 195\ O_2 + 2\ H_2O \rightarrow C_5H_7NO_2 + 400\ NO_3^- + H^+$

From: Haug and McCarty, 1972

What is Aquaponics?: Hydroponics: Technique of growing plants (without soil) in water containing dissolved nutrients

Static hydroponic cucumbers in a trash can. (Kratky, 2003)

Commercial hydroponic lettuce farm on Maui

Static hydroponic watercress in 5 gallon bucket (Kratky, 2003)

Types of Aquaponic Systems

- Ebb and flow (reciprocating)
  - Hydroponic support media (gravel, clay balls, cinder, etc.)
- Raft aquaponics
  - Polystyrene sheets
- Nutrient Film Technique (NFT)
  - Rain Gutters
  - Pvc pipe
- Three Components
  - Rearing tank
  - Biofilter
  - Hydroponic component

Solid support media for ebb and flow systems

Black Cinder

Pea gravel

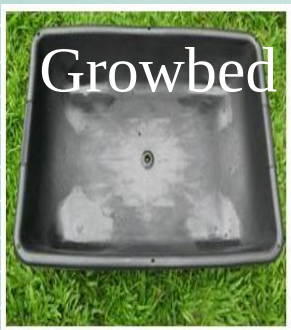
Expanded Clay Balls

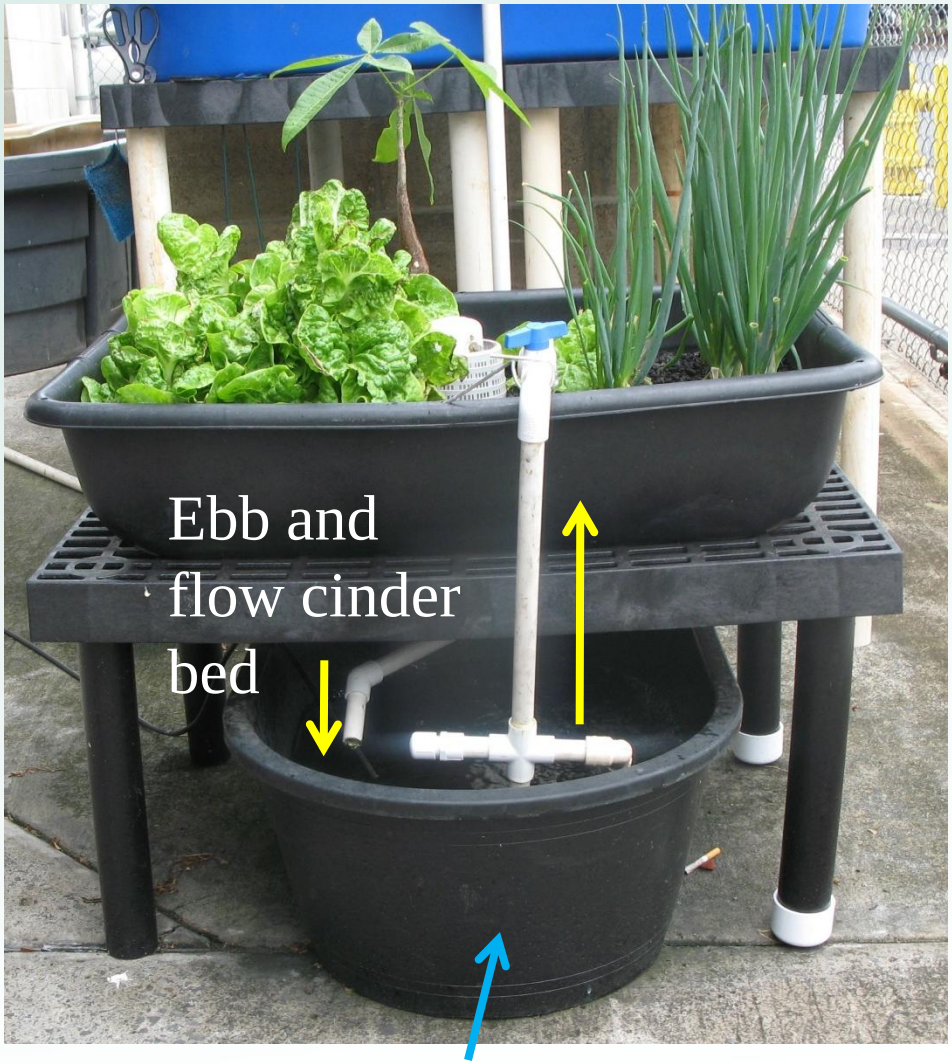
A key part to an ebb and flow growbed is the bell siphon.

You can learn more about the bell siphon from the following website. http://www.ctahr.hawaii.edu/oc/freepubs/pdf/BIO-10.pdf

You can grow just about anything in an ebb and flow gravel bed!

The most basic design:





Submersible Pump inside of fish tank

Magnetic Drive Water Pumps (Supreme©):

Pump (gph)	Price	W	Wh/day	kWh/day	Operating Cost/day ($)
250	$84.35	24	576	0.58	0.18
350	$91.90	35	840	0.84	0.26
500	$107.70	45	1080	1.08	0.33
700	$121.45	60	1440	1.44	0.45
950	$191.00	93	2232	2.23	0.69

Recycled HDPE Fish Tanks (Tuffstuff©):

Rectangle Tank		
31”x46”x16”	75gal	$75.90
Oval Tank		
22”x28”x8”	15gal	$20.75
20”x20”x11”	18gal	$23.88
25”x35”x12”	30gal	$28.88
27”x38”x13”	40gal	$37.26
30”x41”x15”	50gal	$46.38
35”x50”x18”	85gal	$67.05
34”x51”x20”	110gal	$75.52
38”x56”x20”	140gal	$121.82
41”x58”x21”	160gal	$130.00
40”x58”x24”	180gal	$165.96

Recycled HDPE Grow Beds (Tuffstuff©):

Lg. Rectangle		
36”x24”x8”	26gal	$15.99
Contractor Sloped Ends		
60”x36”x12”	90gal	$103.30

Darrel Tanaka,
Kailua Elementary

Windward
Community College,
Aquaculture
Complex

Waimanalo Prototype(s)

WCC Aquaculture Complex

Leina’ala Bright

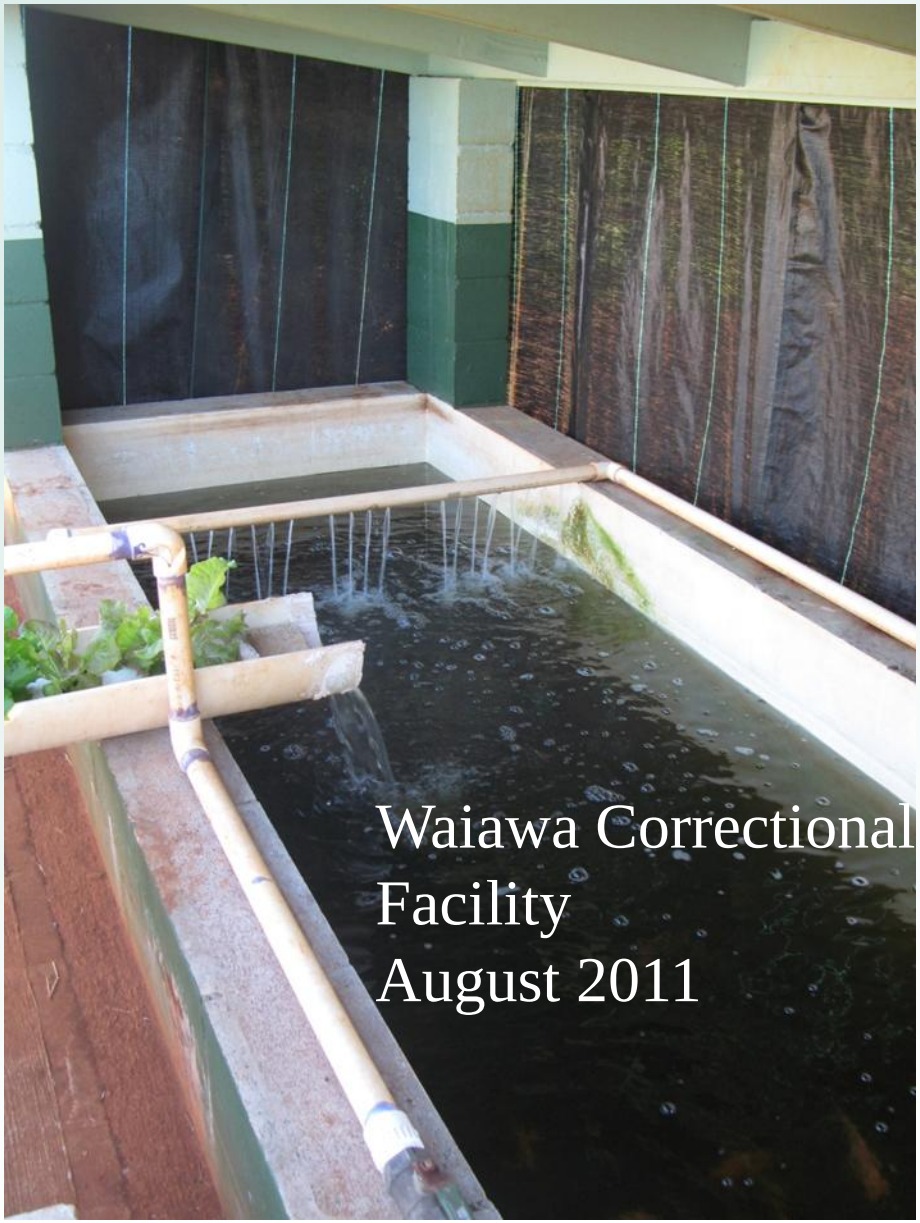
Kawika Kahiapo

Hawaii State Hospital Module

Rearing Tanks

Biofilter
"Reciprocating Ebb and Flow"

Hydroponic Component



Waiawa Correctional Facility
August 2011

MARI'S GARDENS, LLC

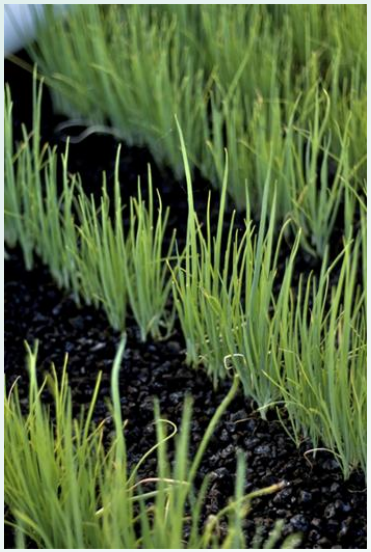
94-415 Makapipipi St Mililani, HI 96789
www.marisgardens.com

What else can I grow besides lettuce?

Blue berries

Cucumber

Beets

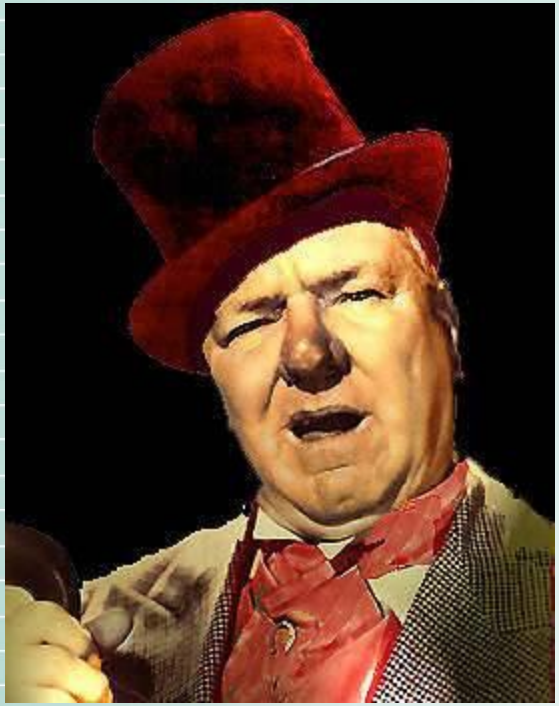


Green onion

Chiso

Cilantro

Tomatoes

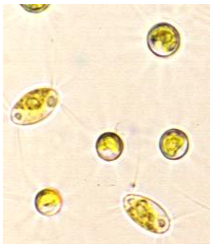


I never drink water because of the disgusting things that fish do in it..

- W. C. Fields

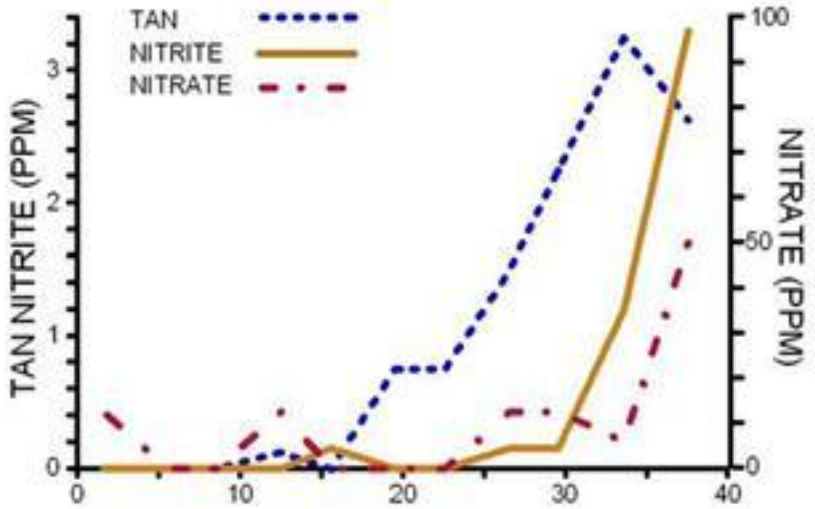
Plants grown in aquaponic systems taste “Fishy” - Anonymous

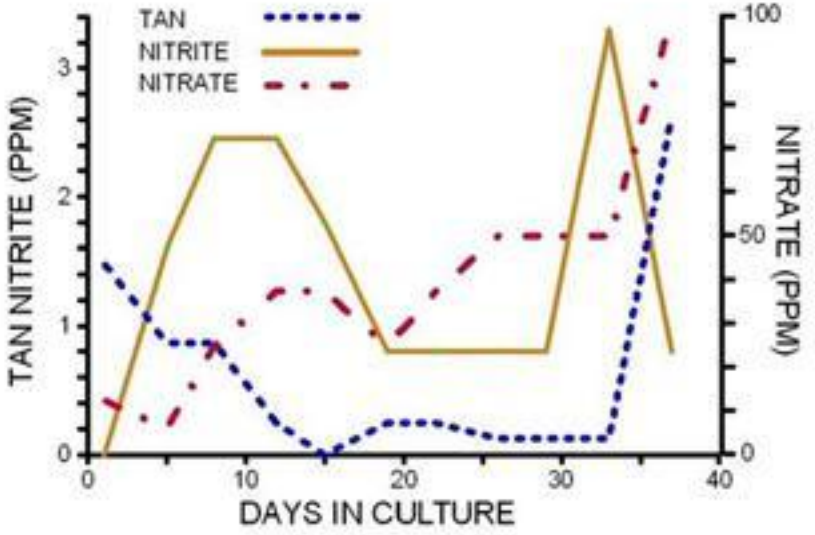
Temporal Changes in TAN, Nitrite and Nitrate in Covered and Uncovered Fish Tanks



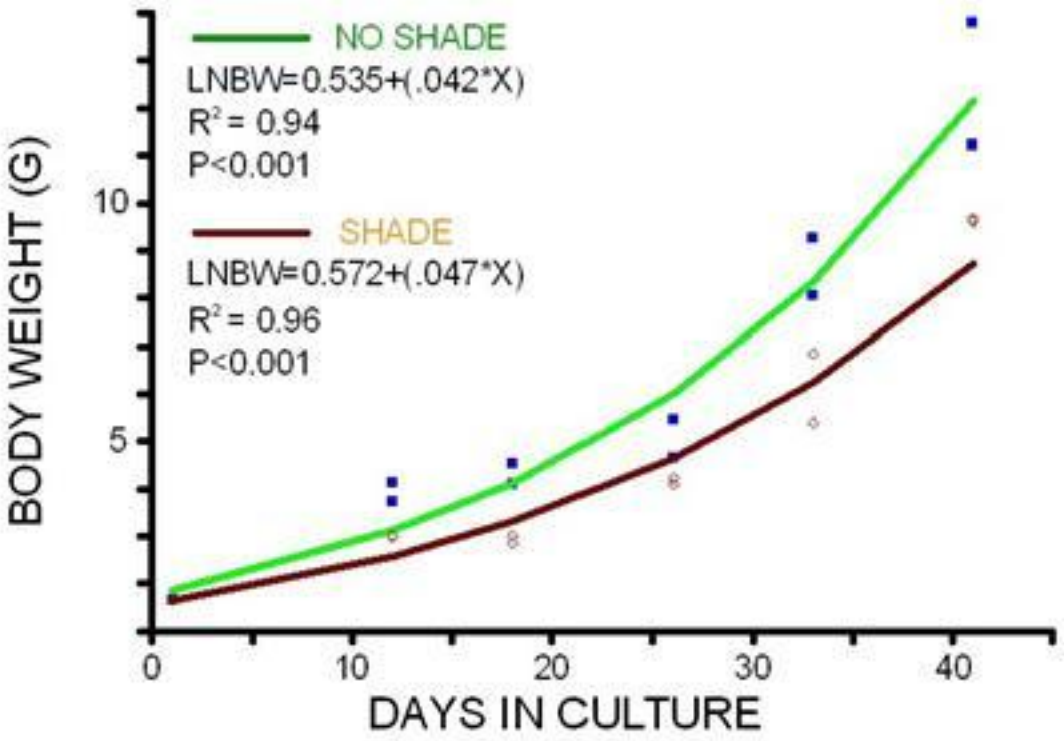
Uncovered tank

Covered tank





Temporal changes in fish growth in covered and uncovered fish tanks



Difference in growth between treatments Is significantly (p<0.001) different, ANCOVA, SYSTAT 1985

No Shade

Shade

Tilapia is the fish used exclusively in aquaponics operations in Hawaii.

- Tolerates low Dissolved Oxygen (DO) levels (e.g., 0.2 ppm)
- Tolerates high Total Nitrate levels (>400 ppm)
- Tolerates high Total Ammonia Nitrogen levels (e.g., >90 ppm) @ pH 6.0
- Tolerates low pH levels (< 5.0)

SmokedTilapia

Alan Wong's RESTAURANTS

Different Feed Treatments

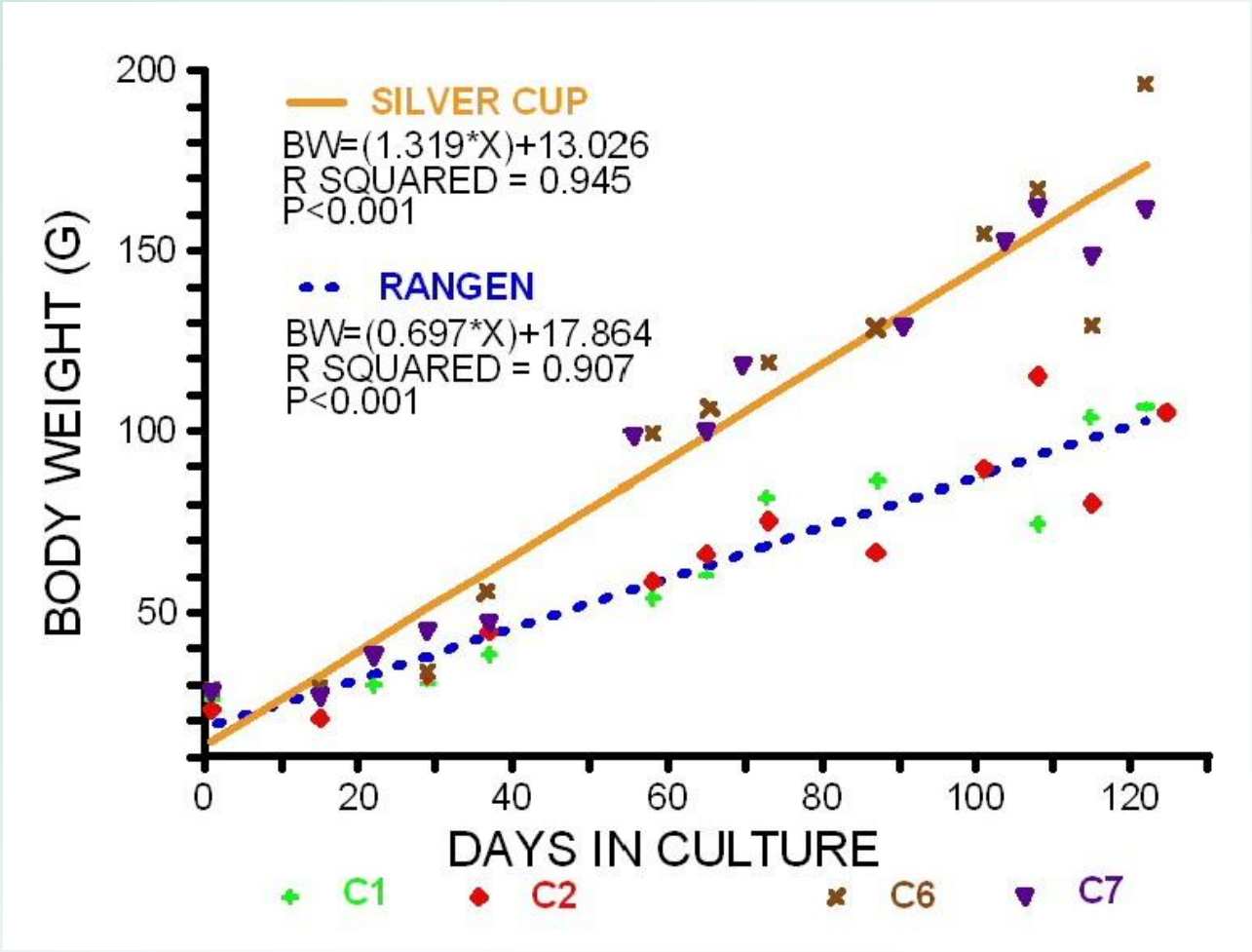
- Rangen 350 Catfish Feed:
  - Crude Protein……35.0%
  - Crude Fat……..……5.0%
  - Crude Fiber……..5.0%
  - Ash……...10.0%
  - Phosphorus……..1.0%

Retail Price
$ 0.63/ lb

- Silver Cup Steelhead Feed:
  - Crude Protein…..….45.0%
  - Crude Fat……....16.0%
  - Crude Fiber……..….3.0%
  - Ash……...12.0%
  - Phosphorus…..……...1.2%

Retail Price
$ 0.77/ lb

Growth of Tilapia Fed Two Different Feeds



Fish being fed the Rangen feed will take an estimated 289 additional days to reach 450g (e.g, 1 lb)

Summary of effects of different feeds

	Rangen	Silver Cup
Net Gain ($)	$8.62	$39.60
FCR	0.75	1.09
Harvest Density (kg/m^3)	10.35	19.03
Survival (%)	98.5%	98.9%

Fish Quality: Significant ($p<0.05$) difference in whole carcass crude fat detected between treatments

Rangen	Silver Cup
26.1% Fat	33.2% Fat


Tilapia Cakes

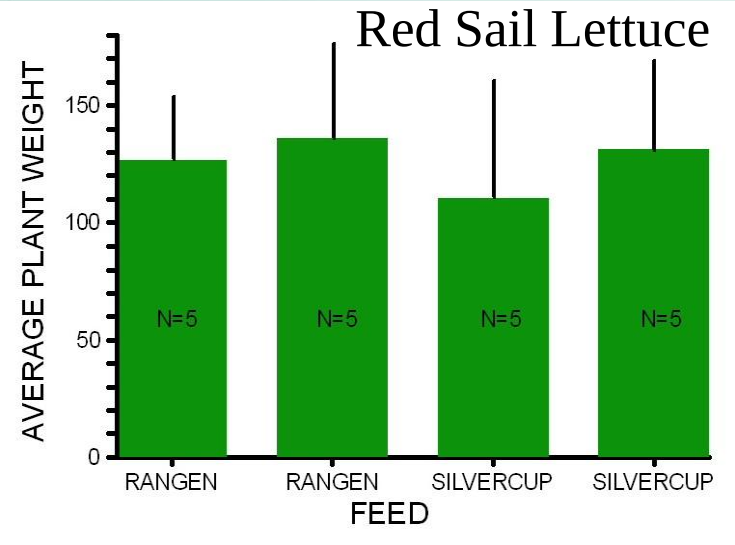

Steamed Tilapia

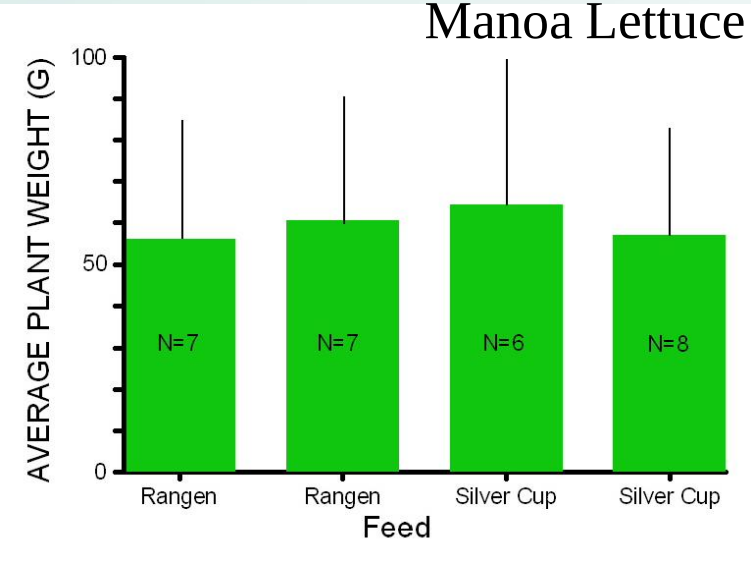

Baked Tilapia

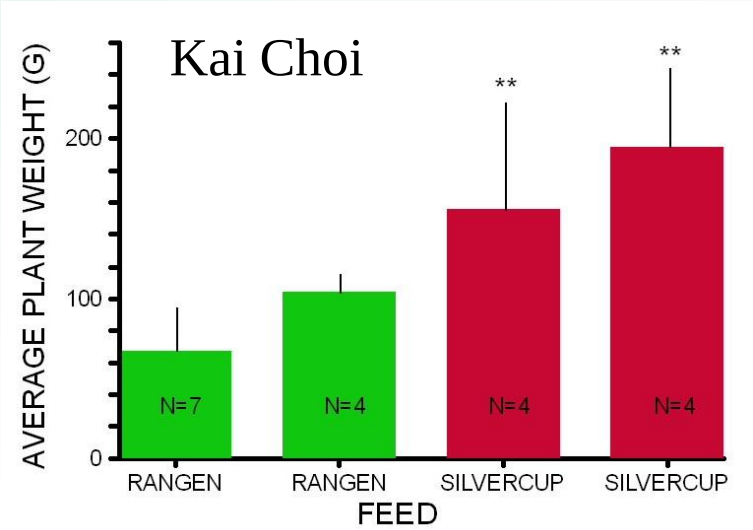
Water Quality Parameters: Nutrients

	Rangen		Silver Cup		Statistics (p-value)
Total Nitrate (ppm)	31.9	14.6	79.8	30.9	p<0.01
Total Nitrite-nitrogen (ppm)	0.6	0.4	0.9	0.4	0.4226
Total Ammonia – Nitrogen (ppm)	0.3	0.5	2.0	1.4	p<0.05

Growth Of Plants In Response To Two Fish Feeds







Nutrient Profiles of Fish Food, Effluent and Static Hydroponic Recipes

WCC Testing Unit

WCC Static Hydroponic Control

Macro and Micro Nutrients	Fish Food (ppm)	WCC Aquaponic System (ppm)	**Static Hydroponic (ppm)
Nitrogen	686,000,000	38.42	158.00
Phosphorus	124,000,000	2.34	40.00
Potassium	75,000,000	9.26	200.00
Calcium	195,000,000	17.88	200.00
Magnesium	18,000,000	8.97	50.00
Iron (Fe)	282	0.04	3.38
Manganese	38	0.12	0.70
Zinc	124	0.08	0.22
Copper	11	0.03	0.40
Boron	9	0.04	0.62

**Hydroponic recipes from: Jones, Resh, Steiner, Wilcox and Snyder

ADAPTING AQUAPONICS SYSTEMS FOR USE IN THE PACIFIC ISLANDS

CENTER FOR TROPICAL AND SUBTROPICAL AQUACULTURE

CSREES EDUCATION RESEARCH EXTENSION USDA

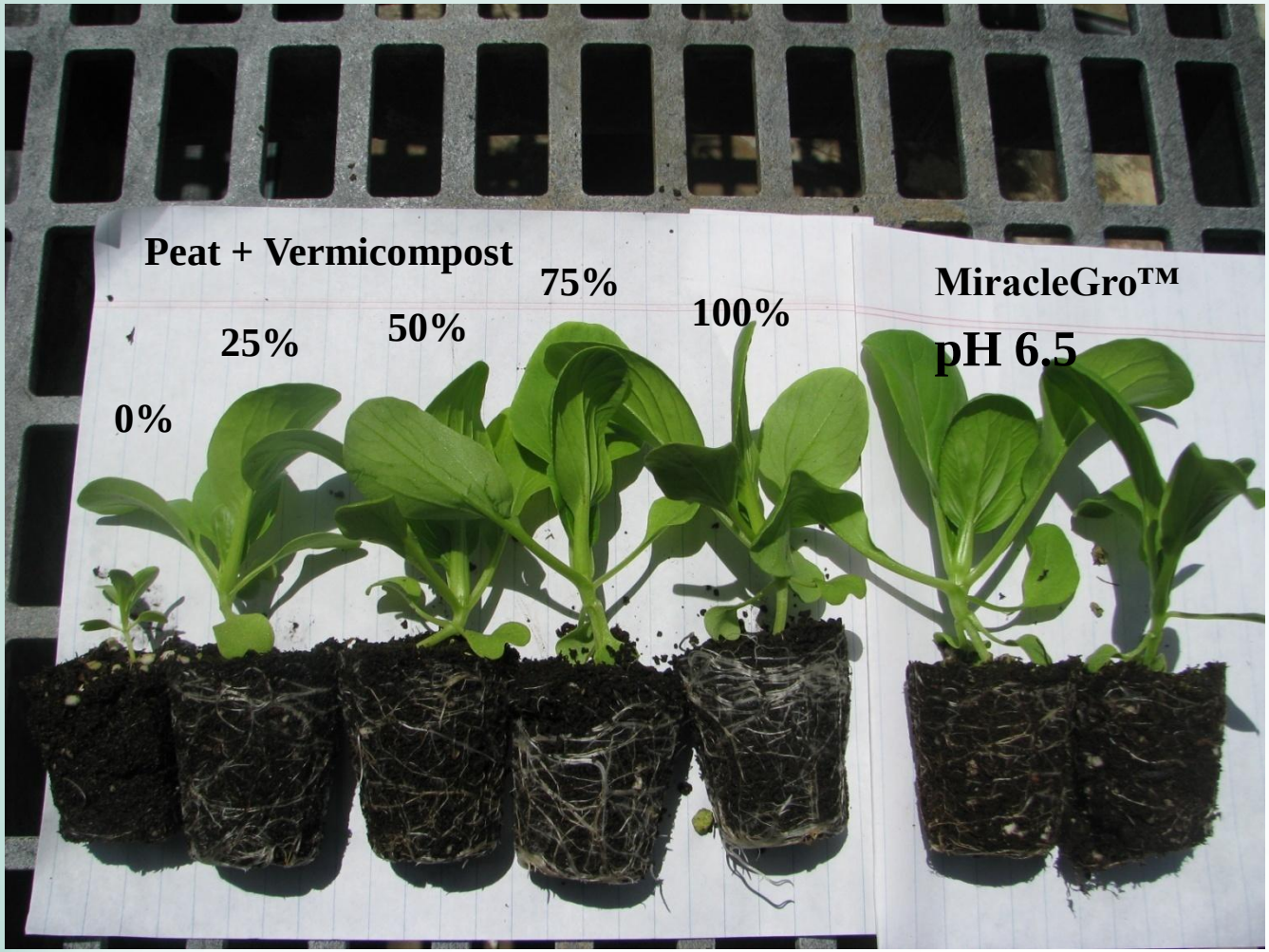
Mass balance of nitrogen. Of total nitrogen input into the system as feed, about 27% is captured as fish flesh, about 43% is captured as lettuce biomass, and a small fraction is lost as nitrogen gas or as solids used to fertilize garden plants.

Tank	Fish biomass (%)	Lettuce biomass (%)	Denitrification or solids (%)
T1	26	40	34
T2	32	41	27
T3	22	49	29
Mean	27	43	30

The amount and sources of denitrification still need to be identified.

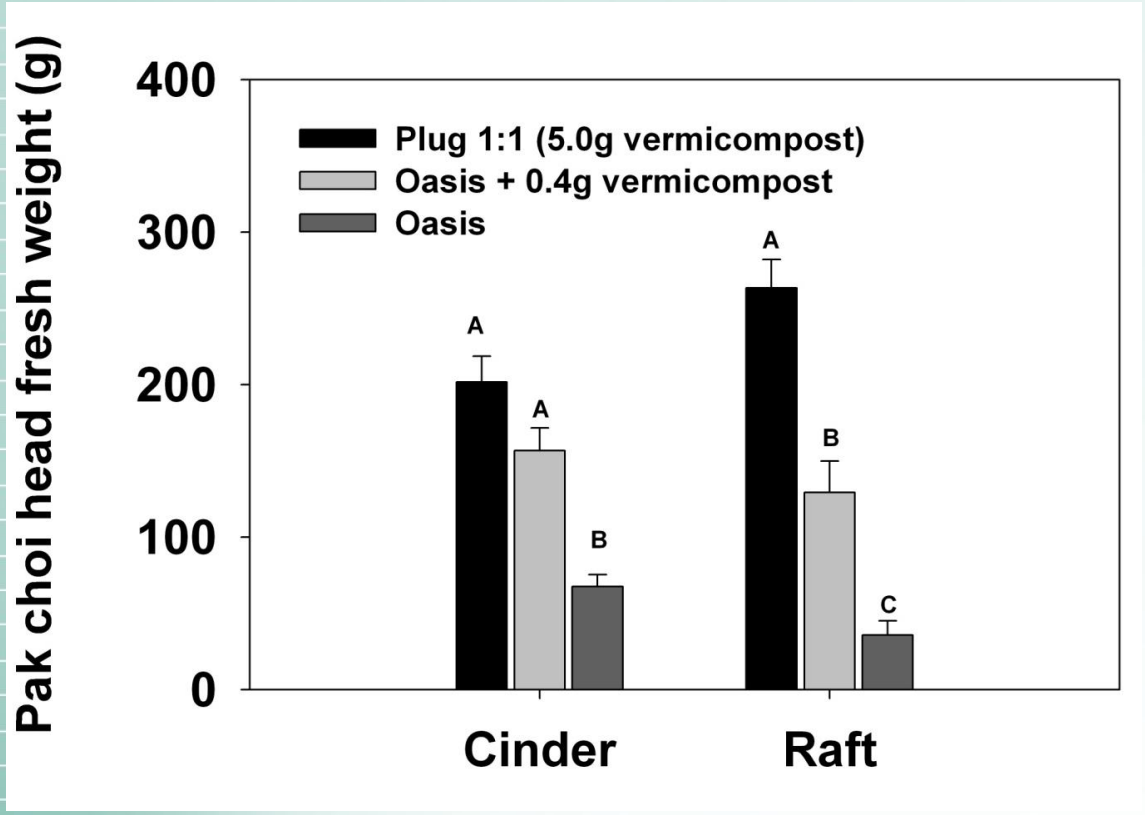
Assessing the utility of vermicast tea for pH remediation and as a source of micronutrients

Seedling Production

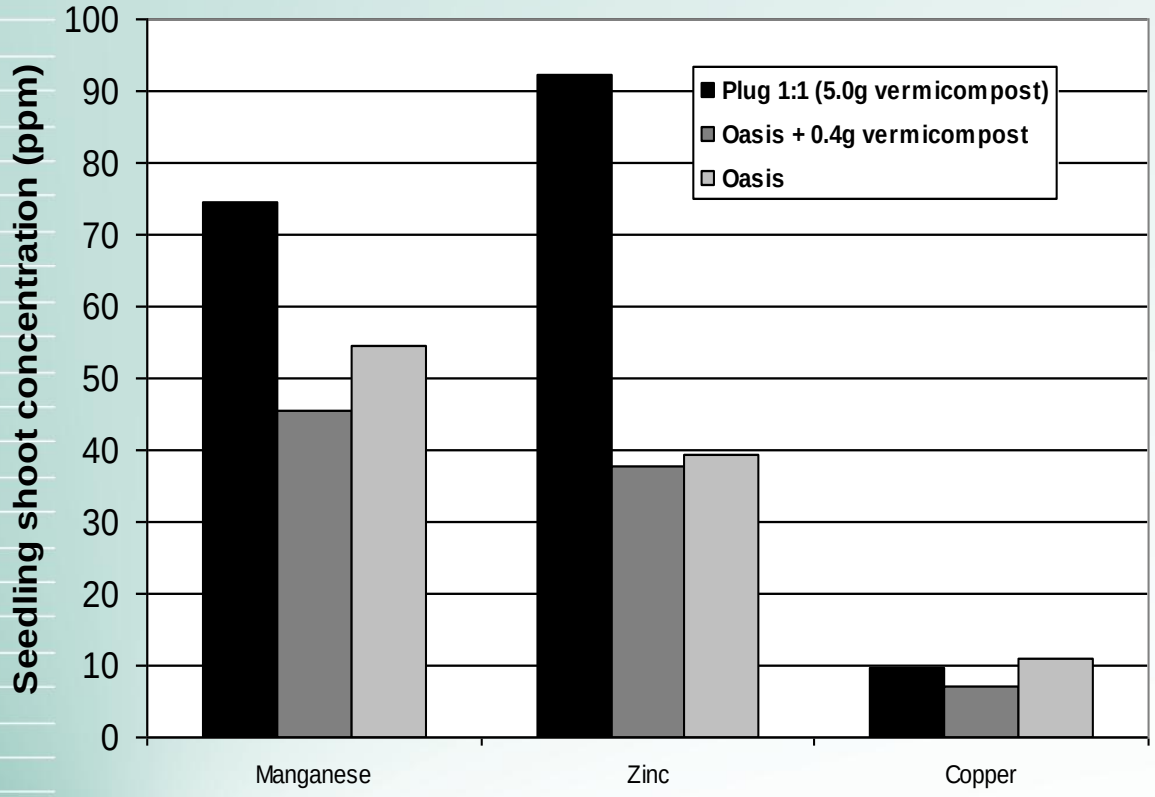


pH 5.0

Impact of seedling media on aquaponic pak choi yield



Are we priming seedlings and avoiding deficiencies?



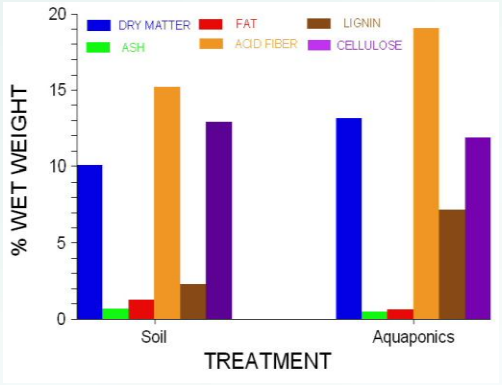
Ongoing observations on-farm

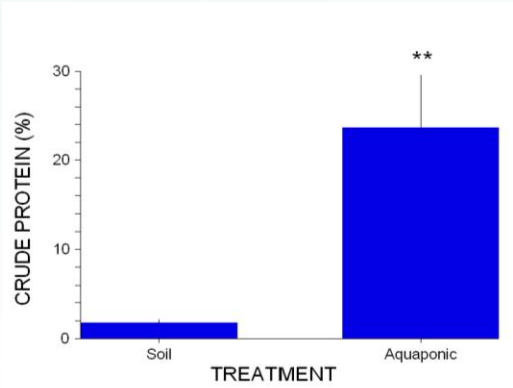
Are there differences in plant performance grown aquaponically versus in soil ?

Bright, L., et.al., 2011. A Hawaiian Herbal Medicine Cabinet Through Aquaponics. 23rd Annual College of Tropical Agriculture and Human Resources & College of Engineering Student Research Symposium. Agricultural Science Building, University of Hawai‘i at Mānoa. April 8-9, 2011.

Olena in soil

Olena in Aquaponic





Extension and Outreach

Strengthening Communities: Waimanalo Prototypes

Kawika Kahiapo

WCC Aquaculture Complex

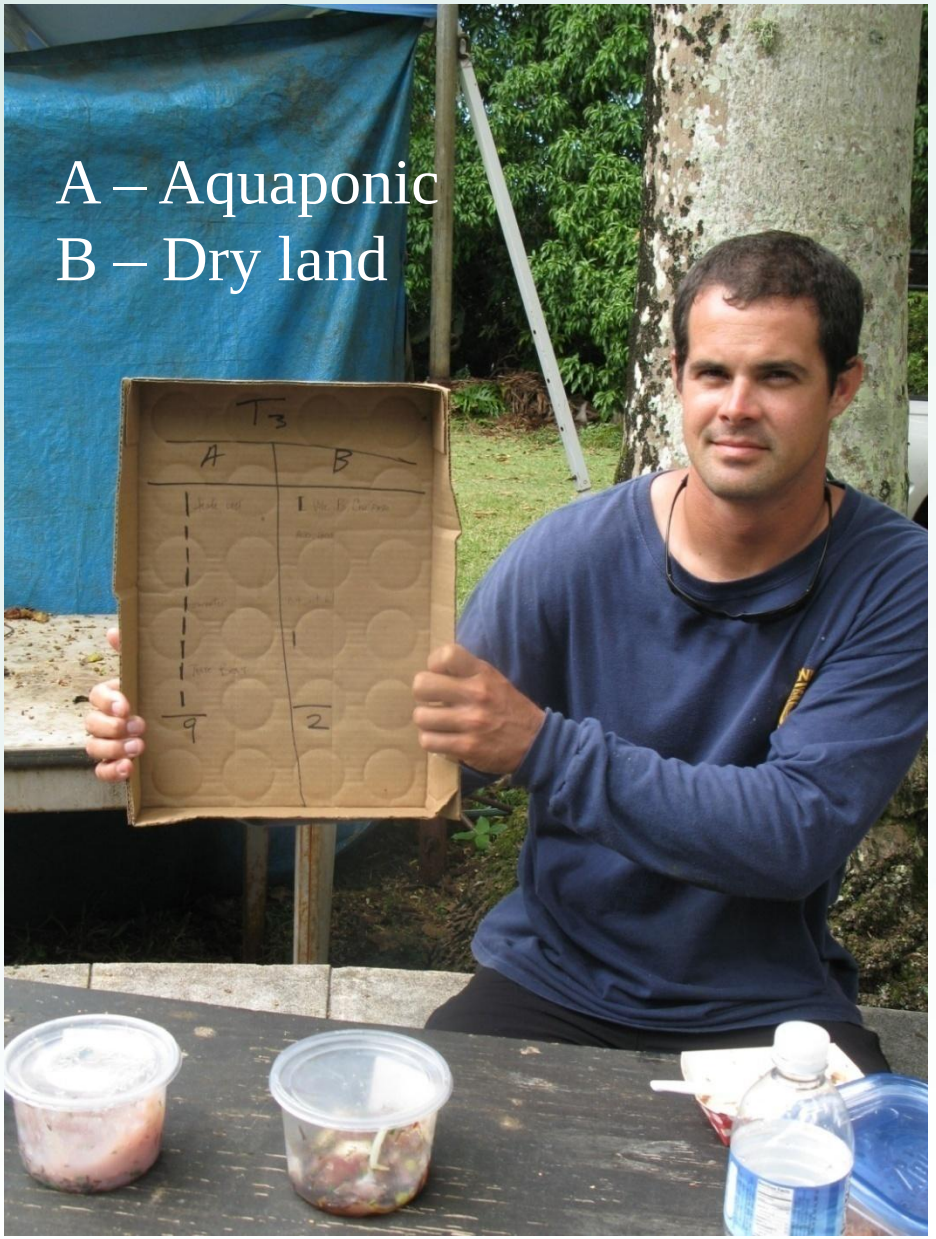
Leina'ala Bright

February 10, 2010

June 22, 2010

Preparation of kalo


B

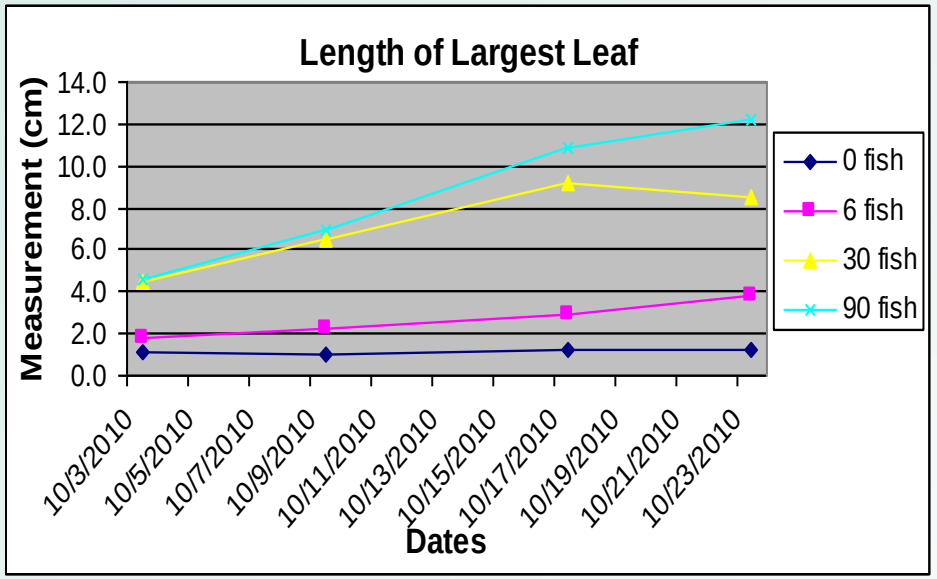

A – Aquaponic
B – Dry land
T3
A
B
1
2
9

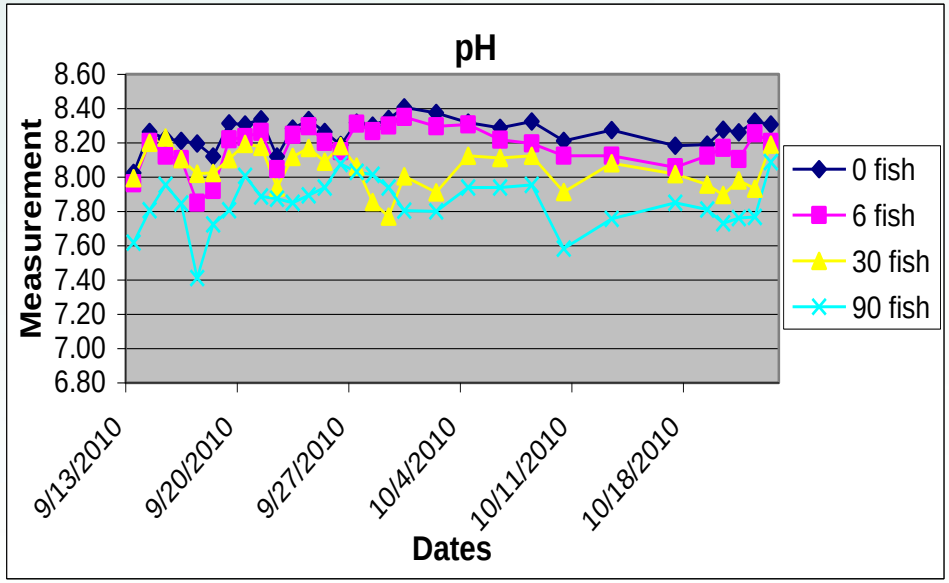
Education: Training the Trainers
Pearl City Highlands Intermediate School

Principal: Ms, Amy Martinson
Lynn Fujioka, ISIS Hawaii
Hapa Farms

The Effects of Varying Fish Densities on Aquaponically Grown Lettuce

Mari Kajiwara & Jolene Fujita
Grade: 10
Mililani High School
Chemistry Honors 2010-2011





MAHALO FOR LISTENING