Composting to Improve Sustainable Food Production Systems, and Water Quality in Pohnpei, Federated States of Micronesia

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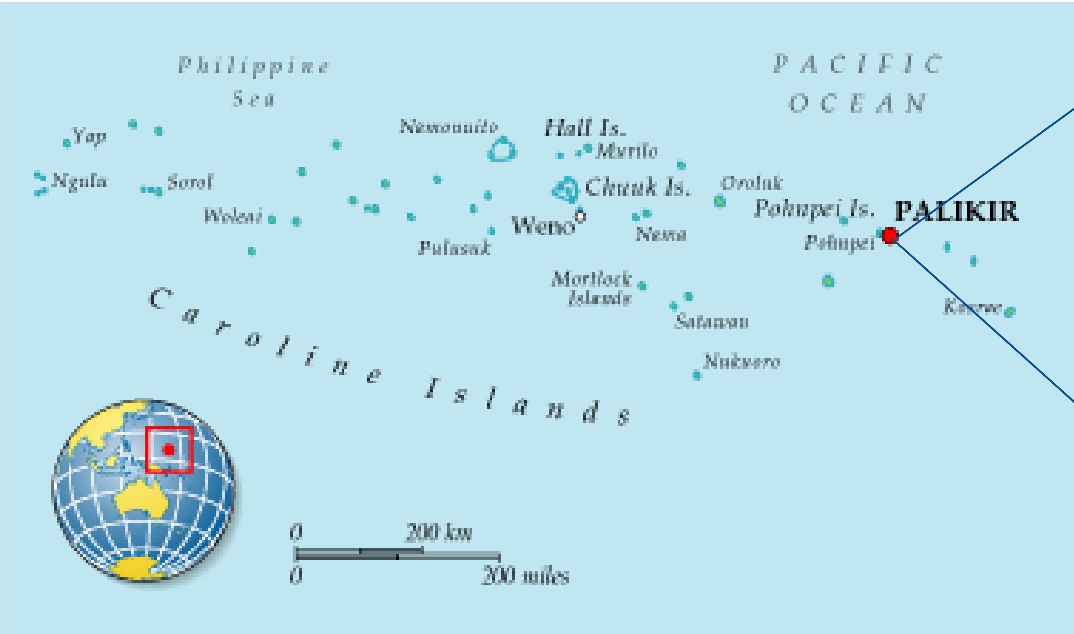
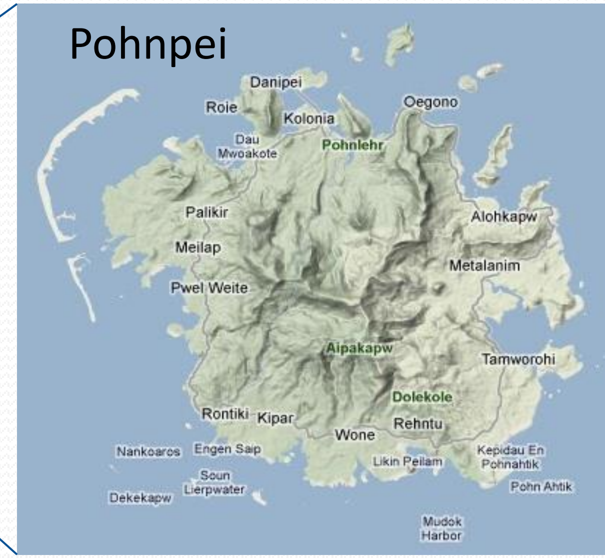
Background

Federated States of Micronesia





Pohnpei

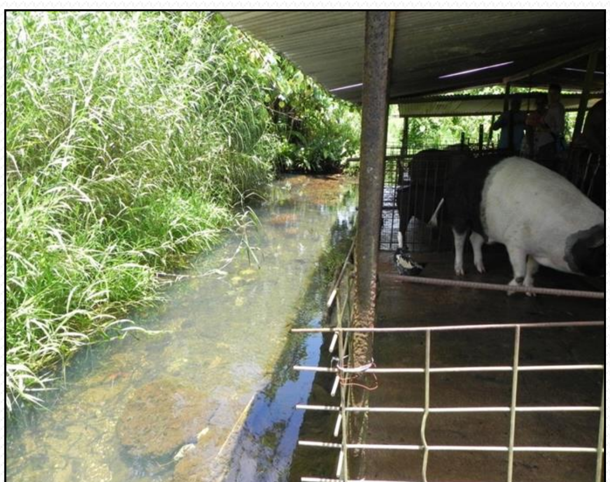
- Second largest island and home of the capital of the Federated states of Micronesia
- Current population ~ 34,000
- Climate
  - Annual rainfall = 4820 mm/year
  - Average temperature = 27°C

Problems Facing Pohnpei

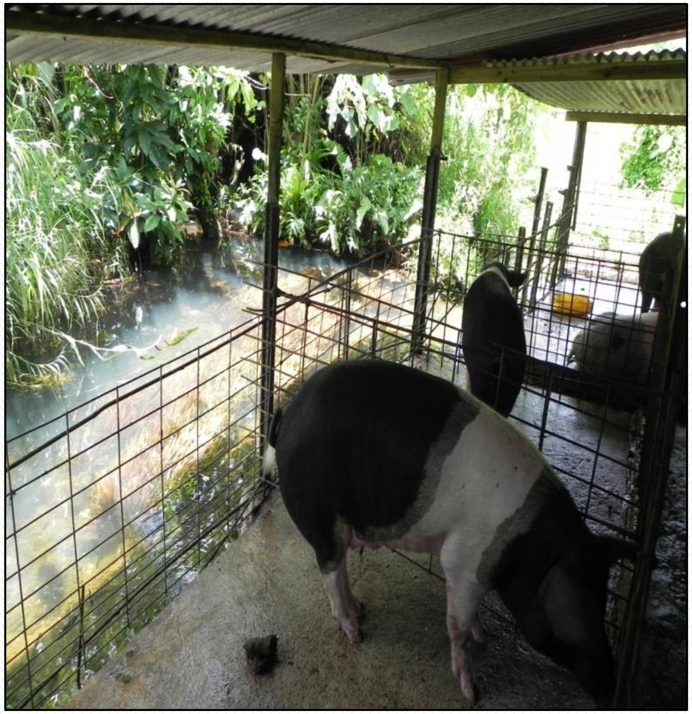
1. Piggery waste management and its adverse effects on water quality.
2. Low soil fertility
3. Food Insecurity

Pigs in Pohnpei

- Pigs (*Sus scrofa*) are culturally important to Pohnpeian society
- ~ 2000+ piggeries Small scale piggeries (15 pigs or less)
- Piggeries are managed using wash down practices



Piggery Waste Management



Amounts of N, P & K washed in to waste stream annually for the average piggery in Pohnpei

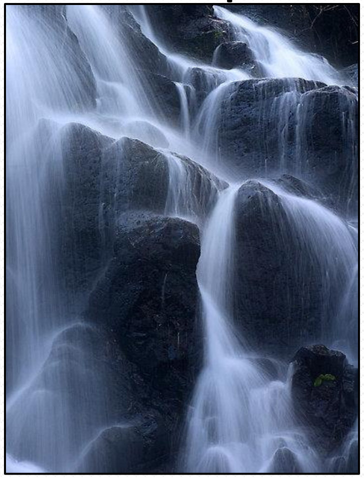
N= 117 kg/yr./piggery

P= 40 kg/yr./piggery

K= 71 kg/yr./piggery

Problems Associated with Piggeries in Pohnpei

- Widespread pollution of water sources
- Excessive use of water resources (~ 90,000 gal/yr./piggery) on a daily basis
- Increased risk of human exposure to leptospirosis
- Wasted nutrient resource as potential soil amendment


Low Soil Fertility in Pohnpei

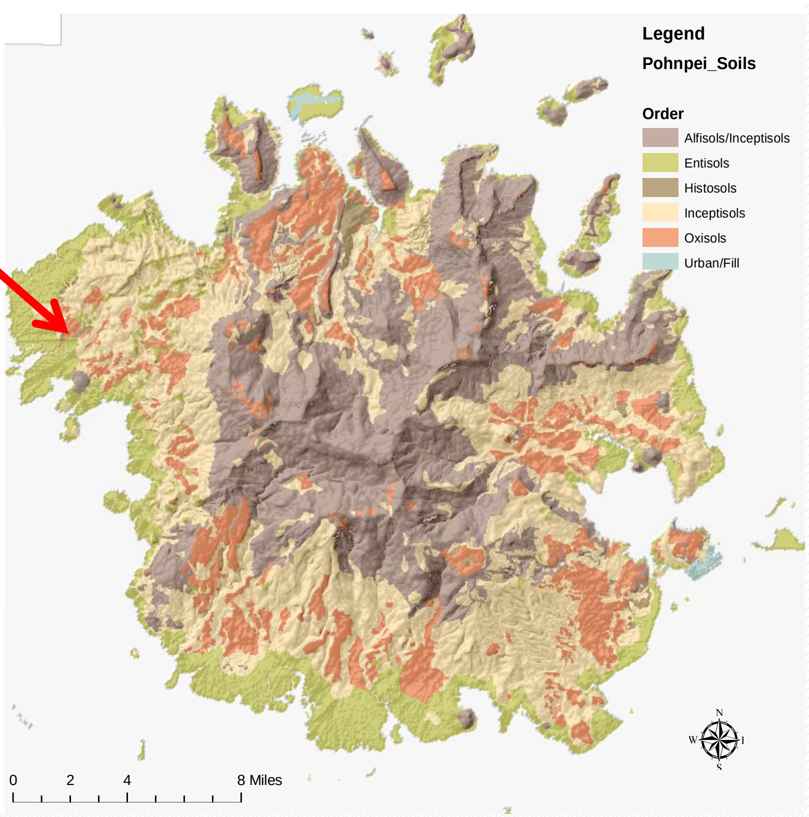
Umpump series: *Clayey, oxidic, isohyperthermic, shallow Typic Acrorthox*

A typical soil in arable portions of Pohnpei (Laird 1982; Giles et al, 2002)

- low nutrient availability
- low pH

Improved production in this soil has depended on chemical fertilizer

Additions of organic materials have also been effective in improving this soil for crop production (Giles et al., 2004)



Food Insecurity in the Pacific

- Current dietary preferences are highly dependent on foreign imported food
- Increasing fuel costs are likely to force Pohnpeians to produce and consume more locally produced food
- Recent efforts have been made to address food security and improved variety of locally available foods

Compost as Potential Solution

- Convert undesirable and potentially harmful waste into a valuable soil resource
- An effective means to recycle unused nutrients

Goal Statements

- Investigate the production of swine manure compost to improve piggery management and sustainable food production systems in Pohnpei

- Through applied cooperative research, extend information on composting use, benefits, and its implications in piggery management

Objectives & Hypotheses

Objective 1: Determine effect of rate of compost application on Kai Choy (*Brassica juncea*) yield

Hypothesis: Compost can be used as an equivalent substitute for chemical fertilizer

Objective 2: Determine residual effects of a single compost application on a second crop

Hypothesis: Yields in a second crop cycle will increase due to residual effects of a single compost application

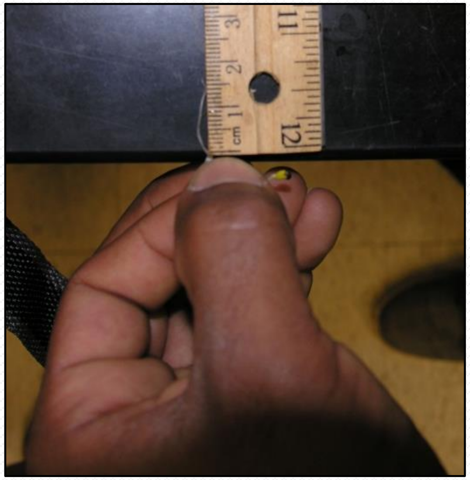
Objectives & Hypotheses

Objective 3: Compare two potential compost recipes of swine manure or fish on composting process and finished compost quality

Hypothesis: Increasing N content of feedstock will enhance composting process and produce higher quality compost

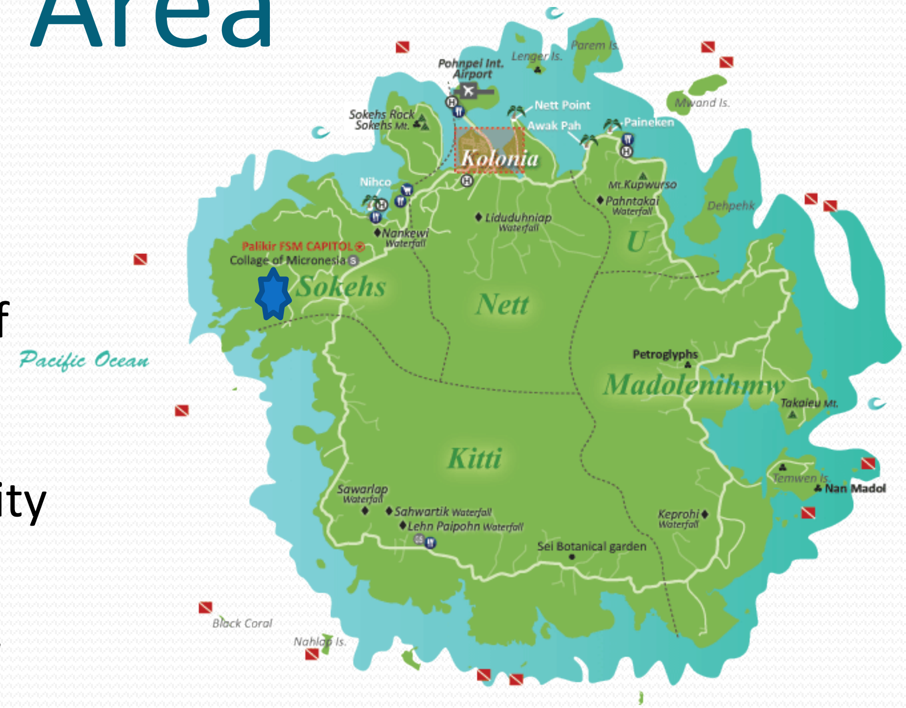
Objective 4: Quantify net returns of composting piggery waste

Methods



Study Area

- Saimon Mix: Cooperating Farmer
  - Compost pioneer
  - Represents younger generation of Pohnpeian farmers
- Small-scale farm in Sokehs municipality
- Soils: Umpump series *Clayey, oxidic, isohyperthermic, shallow Typic Acrorthox*



Kai Choy growth trial

- Rates of application were based around *B. juncea* N requirement

- Assuming: 20% of total compost N is mineralizable

Nutrient and PH values of swine compost used in *B. juncea* field trial.

N	C	P	K	Ca	pH
---------------------------%	----------------------				
1.71	21.50	0.49	0.47	3.37	7.8

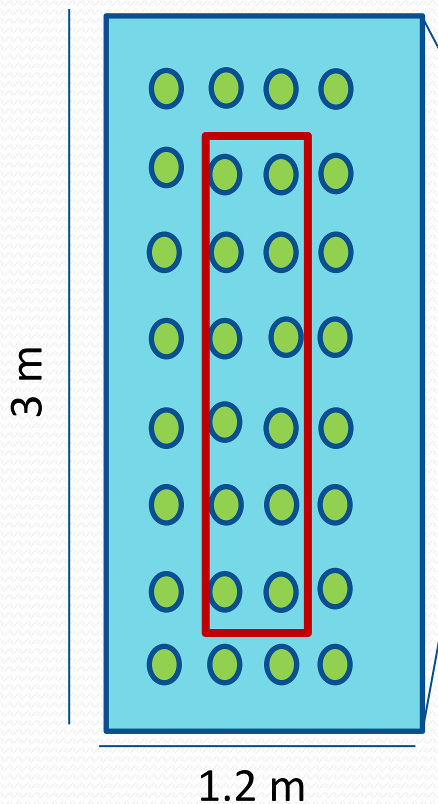
Amendments were broadcast applied and tilled one week prior to planting

Rates of Compost Application kg/ha Used in Kai Choy Field Trial, (10-20-20) Indicates Chemical Fertilizer.

Amendment t/ha	Amendment/3.7m^2 Plot (kg)	kg N/ha
0	0	0
20	7.5	31
40	15	62
80	30	124
160	60	247
320	120	494
2.0*	0.8	124

*(10-20-20) chemical fertilizer
*Lime was applied at 11 kg/plot or 30 t/ha

Kai Choy growth trial

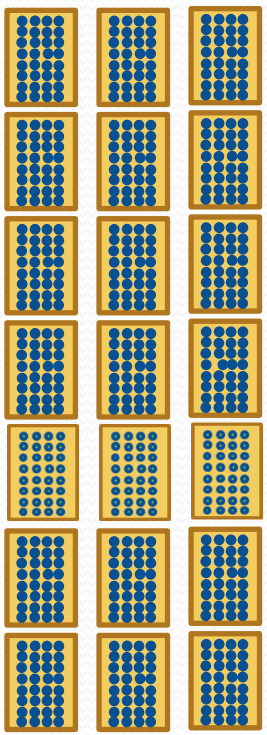


= Kai Choy plant

Experimental unit

= data collection area

- Dimension of unit = 1.2 x 3 m
- Randomized complete block design
- Each treatment in triplicate
- 21 total plots



Kai Choy growth Trial

Plants were grown in nursery for three weeks

Seedlings were transplanted by hand

Sevin® pesticide was used to minimize grasshopper damage

Weeds were uprooted but not removed

Data Collection

- Soil Sampling and analysis
- Weekly collection soil samples during 5 week planting
- Samples analyzed with Vernier® LabQuest® 2 + Ion Selective Electrodes for:
  - NO_3
  - NH_4
  - pH
  - 1:5 ratio (soil: DI water)

Kai Choy Growth Trial

- Harvest at 56 day from seed.
- Crop 2 was planted 3 weeks after first harvest
- Weighed, pressed and dried samples

Plant tissue was analyzed for total C,N,Ca, Mg, P, B, Zn, Mg, Mn, Fe, Cu, & Na (ADSC)

Before and After Harvesting Crop 1

Compost Experiment

- Feedstocks add data on feedstock composition.

Feedstock	C:N	N %	P %	K %	Ca %	Mg %
Hibiscus Leaf	17	2.8	0.4	1.1	2.4	0.5
Hibiscus wood	98	0.4	0.1	1.2	0.8	0.1
Swine Manure	12	2.7	2.2	0.2	1.5	0.6
Fish*	NA					

- Compost recipes:
  - 1/3 hibiscus leaf
  - 1/3 hibiscus wood chip
  - 1/3 swine manure or fish
  - Ratios were by volume

Compost Experiment

- Piles were passively aerated with bamboo chimney

Composting

- Weekly turning
- Watering at turning to maintain ~ 60% moisture



Compost Measurements

- Daily Temperature
- Weekly NO_3, NH_4, & pH
- Vernier® LabQuest 2®
- 1:10 ratio (compost:water)

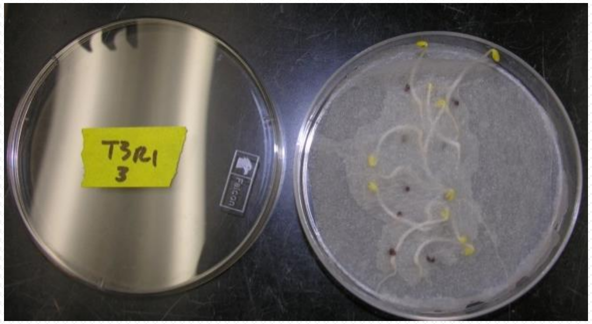
Compost Maturity

- Germination Index(Zucconi et al., 1981; Tiquia & Tam 1996)

$$\text{Relative seed germination (\%)} = \frac{\text{(\#seeds germinated in final compost extracts)}}{\text{(\# seeds germinated in control)}} \times 100$$

$$\text{Relative root growth (\%)} = \frac{\text{(Mean root length in final compost extracts)}}{\text{(Mean root length in control)}} \times 100$$

$$\text{Combined germination index} = \frac{\text{(\% Relative seed germination)(\% Relative root growth)}}{100}$$



Final compost C:N was also used as an indicator of maturity (Kuo et al., 2004)

Partial budget

- Composting vs. current wash down methods

- Compared labor of each practice during one month

- Two final uses of compost were used to create partial budget
  - Composting for sale as a commodity
  - Using compost as a soil amendment

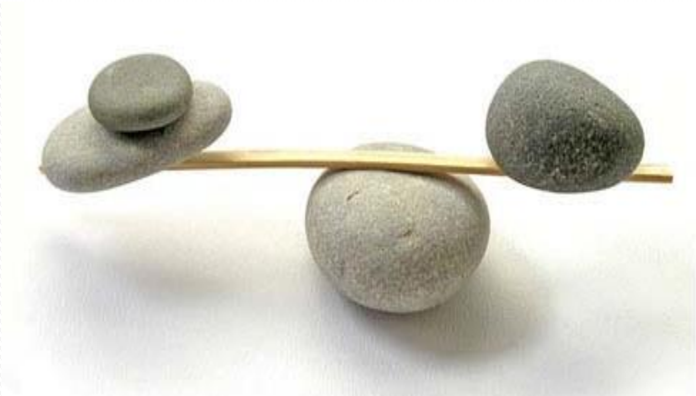
- Assumptions:

  Average Piggery size contains 15 pigs

  1.54 tons manure produced/month

  7 compost piles can be made

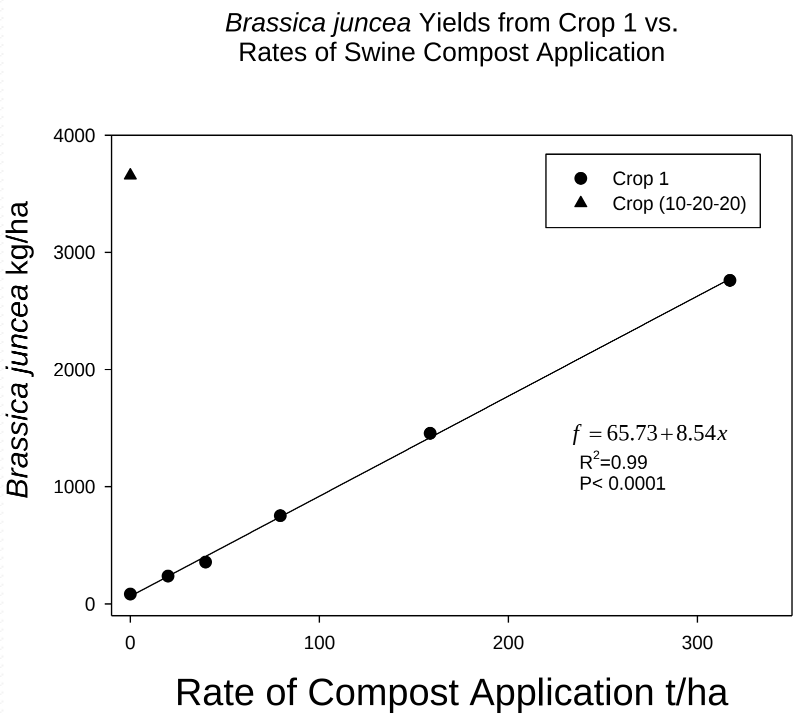
  Labor Cost = $1.00/hour




Results & Discussion

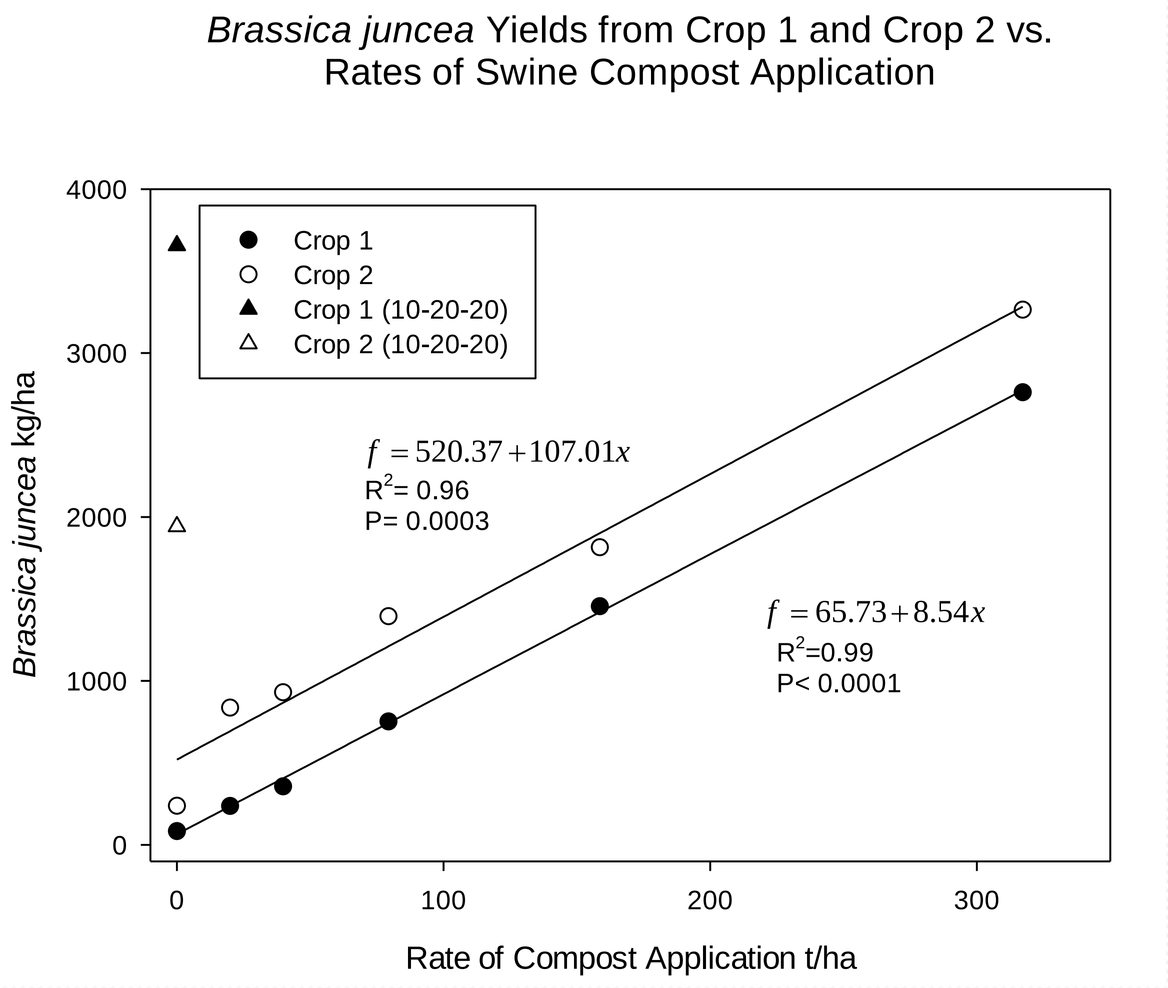
Kai choy Yields Crop 1

Objective 1: Determine effect of rate of compost application on Kai Choy (*Brassica juncea*) yield



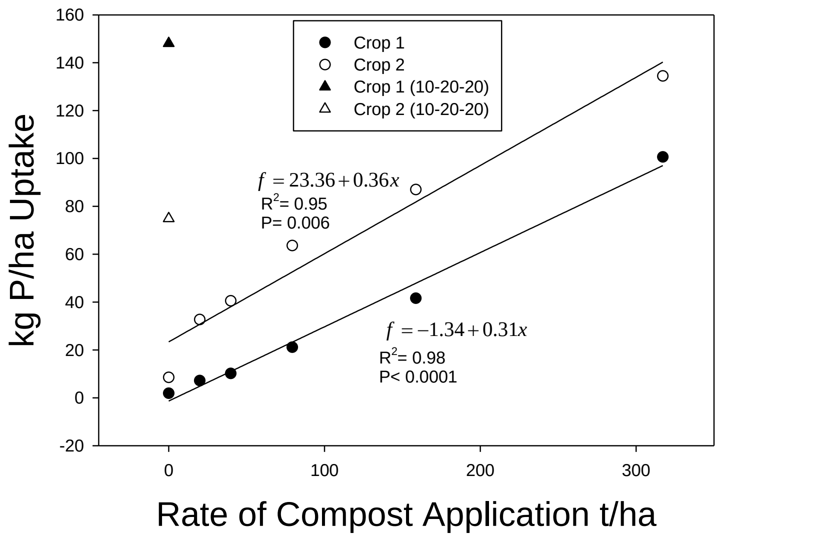
Kai choy Yields: Crop 2

- Crop 1 vs. crop 2 yield and control

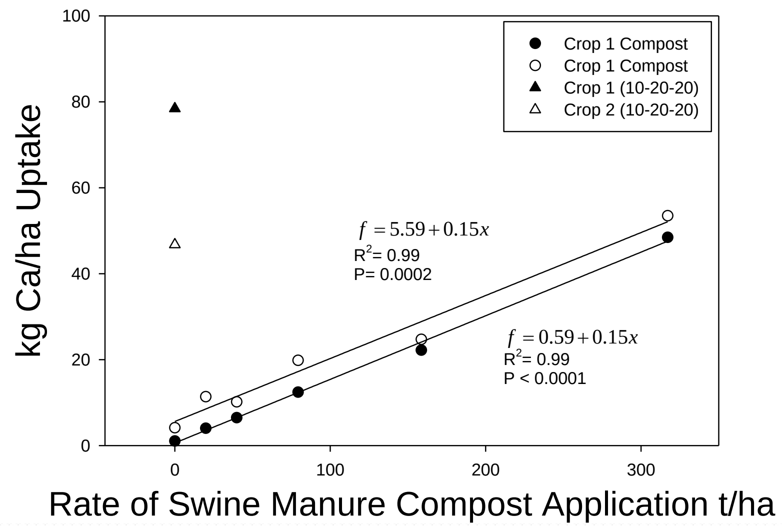


Residual Supply of N, Ca & Mg

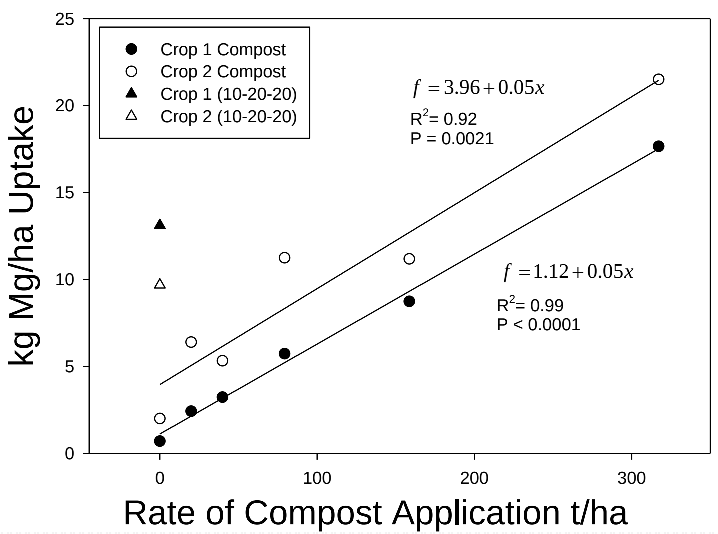
Brassica juncea N uptake: Crop 1 and Crop 2 vs Rate of Compost Application



Brassica juncea Ca Uptake: Crop 1 and Crop vs. Rate of Compost Application



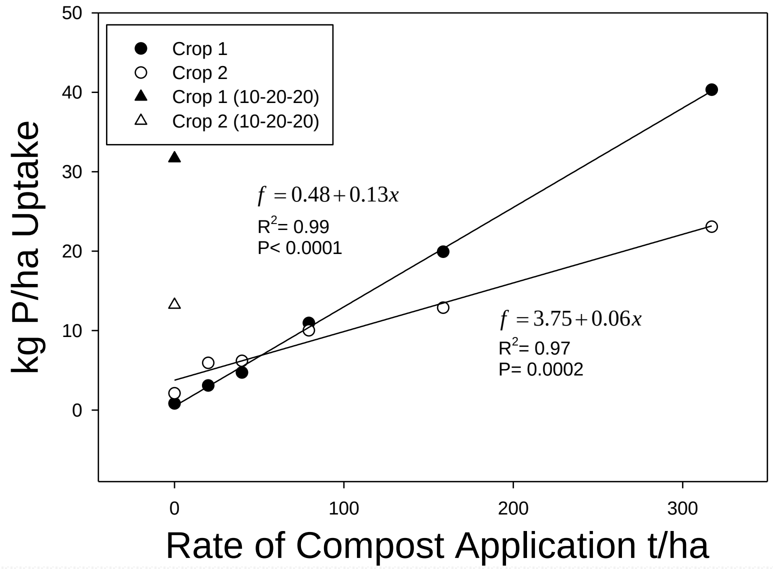
Brassica juncea Mg Uptake: Crop 1 and Crop vs. Rate of Compost Application



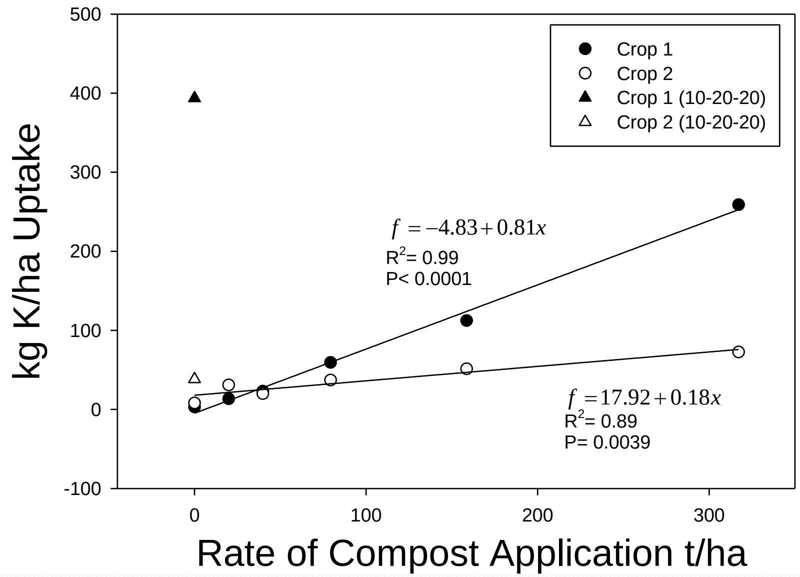
Lower supply capacity for P & K

P

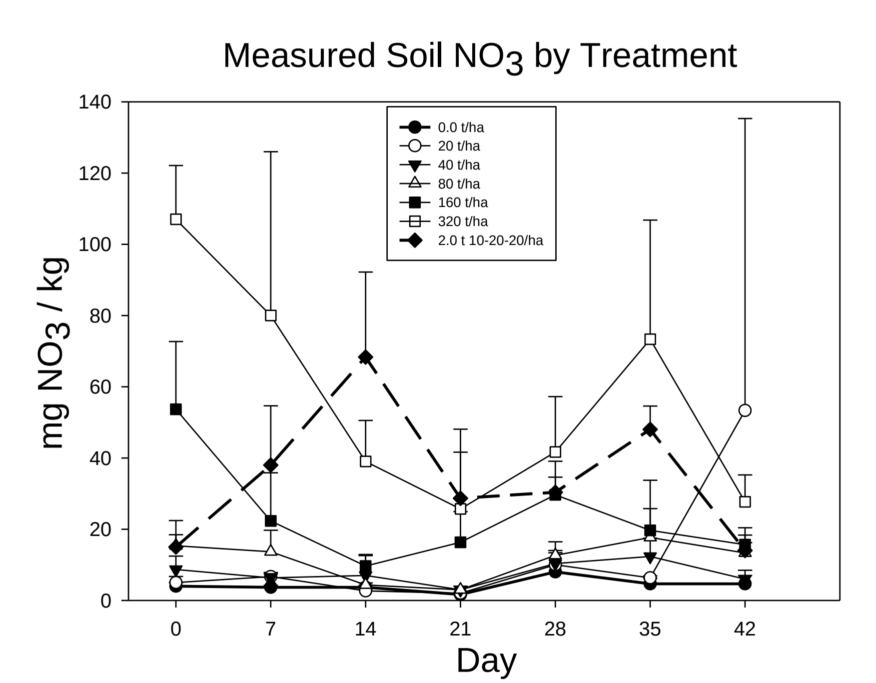
Brassica juncea P Uptake: Crop 1 and Crop 2 vs. Rate of Compost Application



Brassica juncea K Uptake: Crop 1 and Crop vs. Rate of Compost Application



Soil NO_3: Crop 1

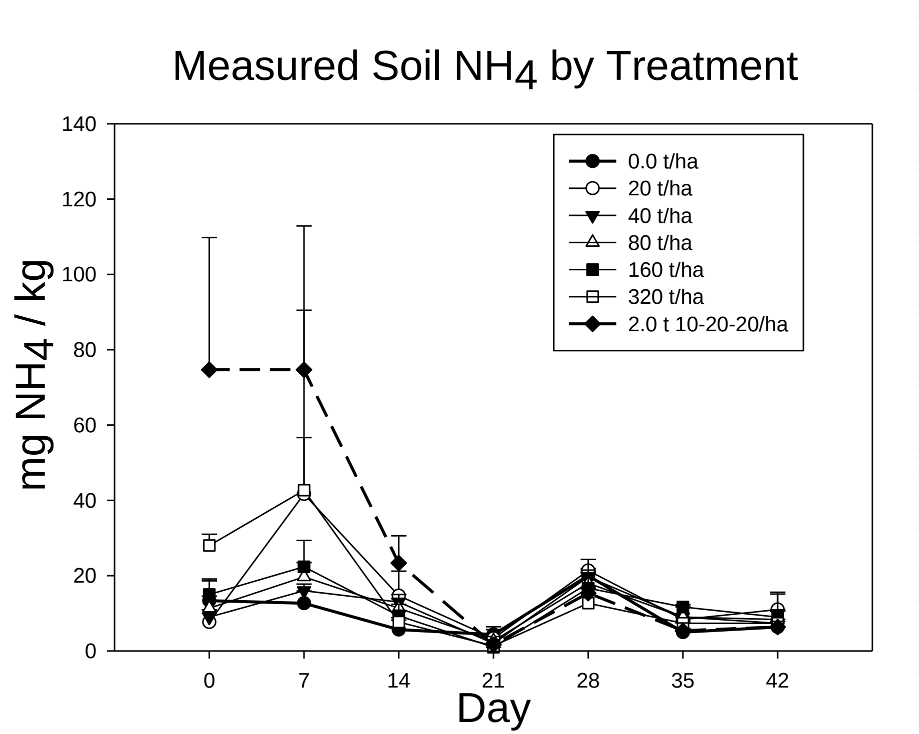


Measured of mean soil NO_3 (mg/kg) by varying rates of compost application vs. chemical fertilizer.

	Rates of Swine Compost or Chemical Fertilizer (10-20-20) Application					
Day	20 t/ha	40 t/ha	80 t/ha	160 t/ha	320 t/ha	2.0 (10-20-20) t/ha
0	5.0 (1.73) c	8.7 (3.79) c	15.3 (7.09) c	53.7 (19.04) b	107.0 (15.10) a	15.0(3.46) c
14	2.7 (0.58) b	7.6 (5.57) b	4.3 (0.58) b	9.7 (3.21) b	39.0 (11.53) a	68.3(23.86)a
28	10.0 (4.00) bc	10.3 (3.06) bc	12.7 (3.79)bc	29.7 (4.93) ab	41.7 (15.57) a	30.3 (8.74)ab
42	53.0 (81.98) a	6.0 (1.00) a	13.3 (2.89) a	15.7 (4.73) a	27.7 (7.57) a	14.0(4.36)a

Values of means that share a letter are not significantly different as determined by Tukey's comparison at 5% with ANOVA significance at P<.05. Standard errors are indicated by ()

Soil NH_4

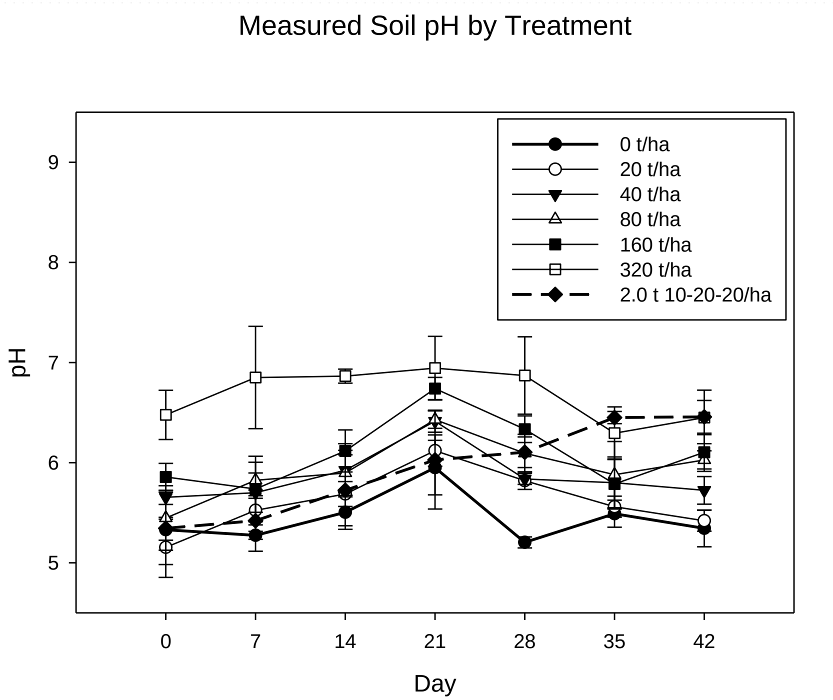


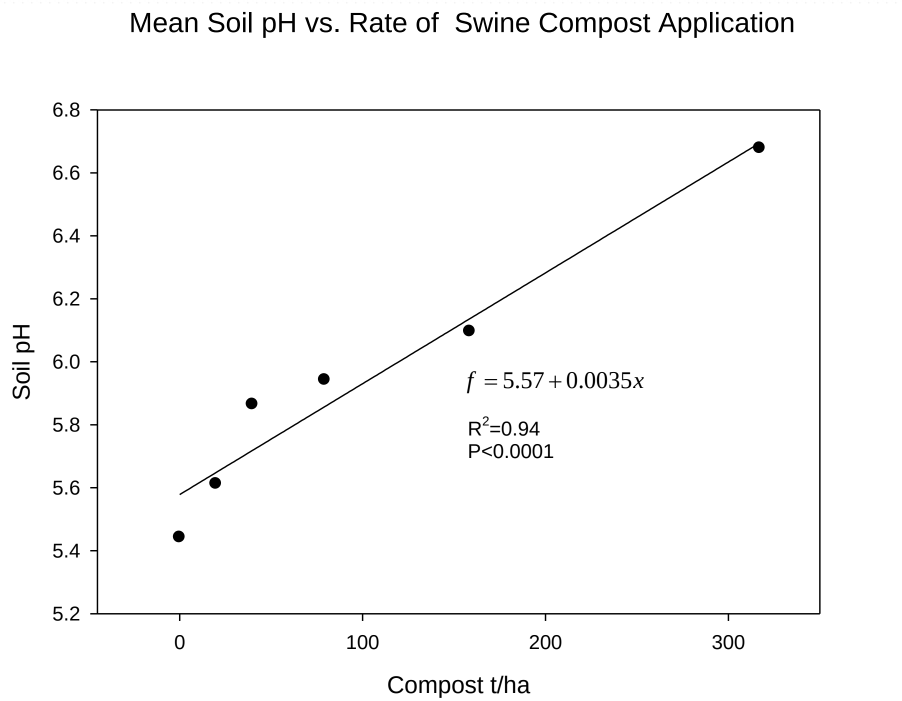
Measured Mean Soil NH_4 (mg/kg) by Varying Rates of Compost Application vs. Chemical fertilizer (10-20-20).

Day	Rates of Swine Compost or Chemical Fertilizer (10-20-20) Application					
	20 t/ha	40 t/ha	80 t/ha	160 t/ha	320 t/ha	2.0 (10-20-20) t/ha
0	7.7 (3.21) [b]	9.0 (1.00)[b]	11.3 (3.21) [b]	15.0 (3.61) [b]	28.0 (3.00) [b]	74.7 (35.12) [a]
14	14.7 (6.51) [ab]	13.0 (2.00) [ab]	11.3 (2.52) [ab]	9.3 (3.06) [b]	7.7 (1.15) [b]	23.3 (7.23) [a]
28	21.3(0.58) [a]	19.7 (4.62) [a]	18.0 (3.46) [a]	16.7 (4.04) [a]	12.67 (4.04) [a]	15.3 (1.15) [a]
42	11.0 (4.58) [a]	7.3 (3.51) [a]	8.3 (2.52) [a]	9.0 (6.08) [a]	7.3 (3.21) [a]	6.3 (1.53) [a]

Values of means that share a letter are not significantly different as determined by Tukey's comparison at 5% with ANOVA significance at P<.05. Standard errors are indicated by ().

Soil pH: Crop 1





Compost was as effective as $CaCO_3$ for liming soils.

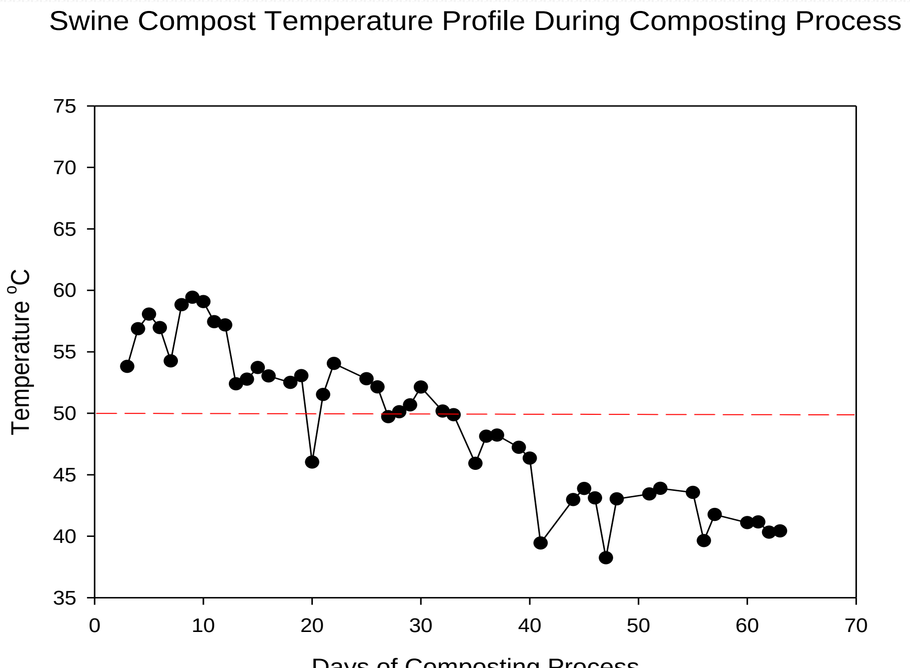
This saves labor because sand is very heavy to transport.

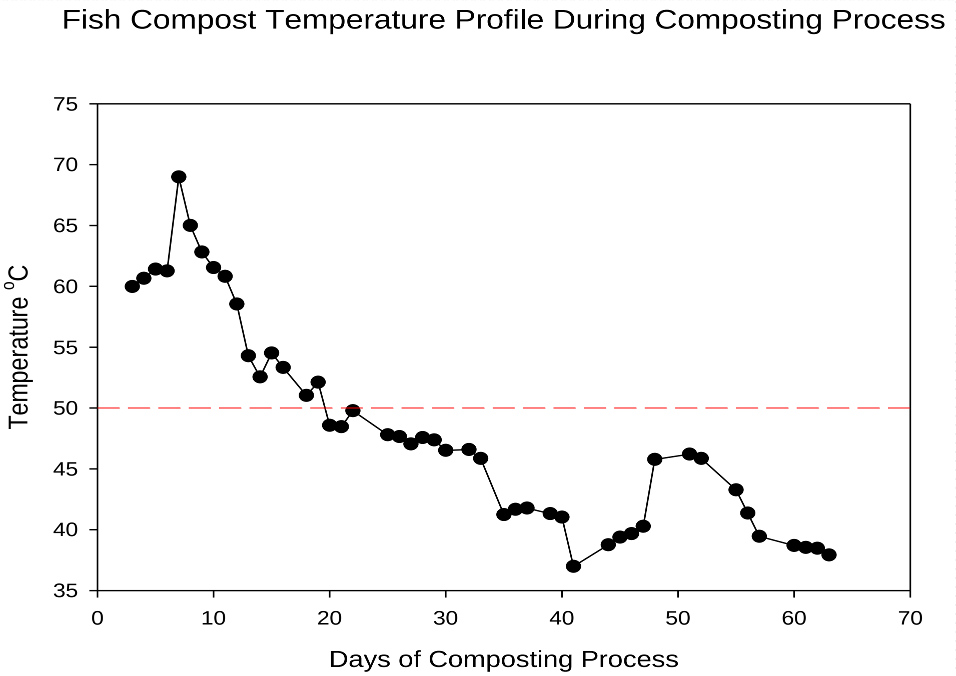
Compost Temperatures

Compost recipe did not have a significant effect on duration of compost thermophilic phase (Temperature > 45 °C)

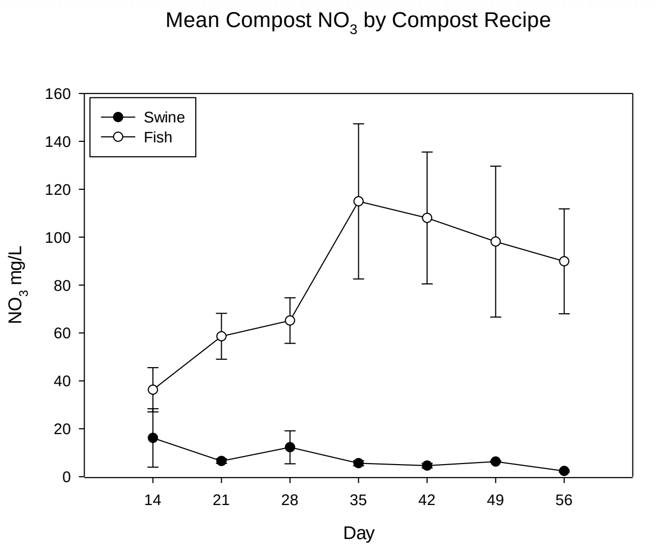
Both composts were able to maintain temperatures > 50°C for more than 7 days

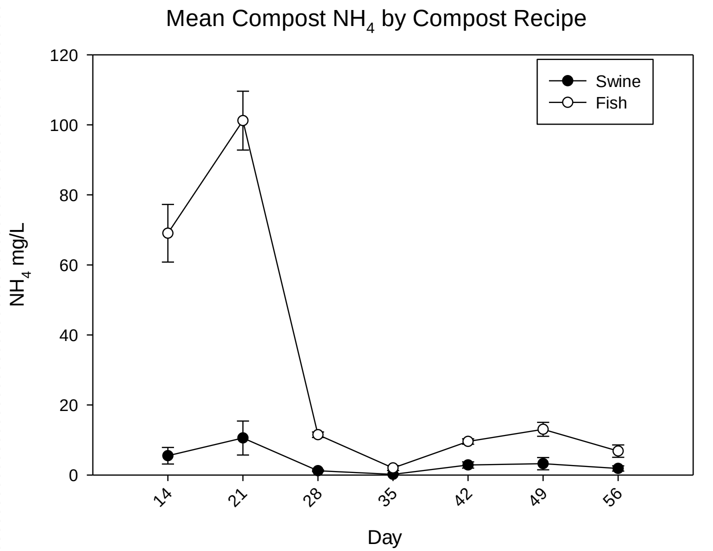
EPA time/temperature pathogen reduction standards for aerated composts. (Walker, J.M, 2001)

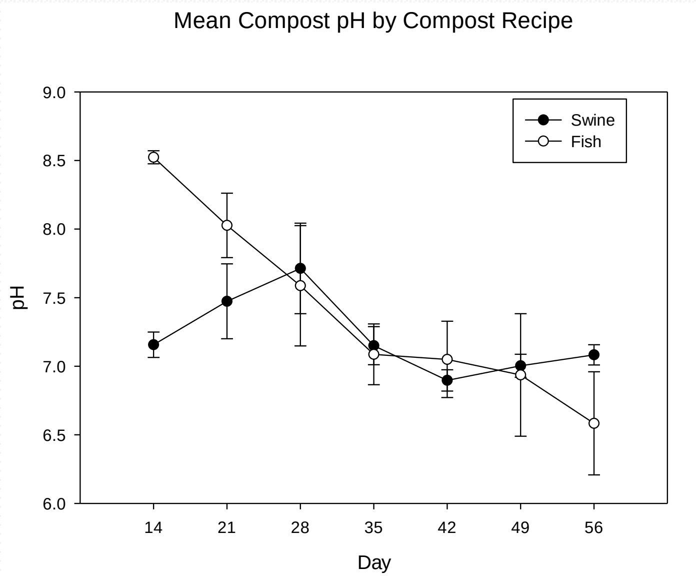




Compost NO_3, NH_4, & pH







Compost maturity (Germination Index)

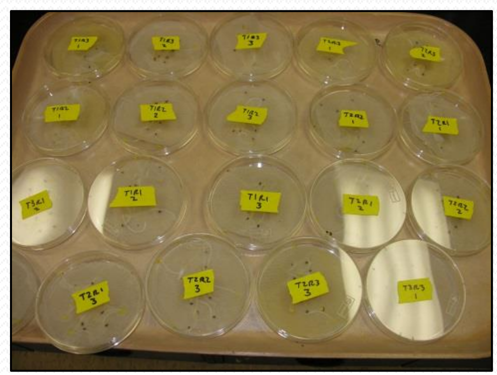
Combined Germination Indexes (GI %) of Each Compost Recipe.

	Compost Recipe		
	DI Control	Swine	Fish
GI %	100	150*	116*

* Values greater than 80% indicate compost maturity.

Both composts were mature!

Final C:N Ratios of both composts were indicative of maturity



Finished Compost

Compost Nutrient Value at 5 months

Selected Nutrient, pH, & EC Values for Finished Composts.

Compost Recipe	pH	EC	C:N	N	P	K	Ca	Mg
		dS/m		%	%	%	%	%
Swine	7.1	1.0	13	1.9	0.6	0.3	1.8	0.8
Fish	6.8	2.7	11	2.5*	0.7	0.4	2.8*	0.6

Fish waste compost produced a better compost in terms of nutrients
Both composts would be viable soil amendments for crop production

Compost before and after

Day 0

2 months

5 months

Partial Budget: Composting

Compost sold at market value

Added Returns		Added Costs	
Market value of compost -	$3.00/cu ft.(1 pile =2.25 cu ft. or $6.70/pile X 7 =$47.25	Manure collection Labor to make compost	7.5 hrs./month 7.50 10 hrs. labor per pile 1 hour to flip (2x per month = $2.00 total=$12.00 x 7=$84.00 $91.50
		Water added during compost (280 gallons)	$0.50
Total added returns	$47.25	total added costs	$92.00
Reduced Costs		**Reduced Returns**	
50% reduction in pig pen wash down 15 minutes/day 7.5 hrs/month	$7.50	None	
Total Reduced Costs	$60.05	Total added costs	$92.00
Net Cost= - $37.25			

Compost used as soil amendment

Added Returns		Added Costs	
yield increase of compost from a single application (118kg/plot) compared to yield from native soil.	$33.00	Manure collection Labor to make compost	7.5 hrs./month 7.50 10 hrs. labor per pile 1 hour to flip (2x per month = $2.00 total=12.00 x 7=$84 $91.50
		Water added during compost (280 gallons)	$0.50
Total added returns	$33.00	Total added costs	$92.00
Reduced Costs		**Reduced Returns**	
50% reduction in pig pen wash down 15 minutes/day 7.5 hrs/month	$7.50	None	
cut labor for watering crops	$150		
		Total added costs	$92.00
Total Reduced Costs	$157.50		
Net Cost= +$98.50 or $65.50 if crop yield not considered			

Partial Budget: Compost

Net Returns for Marketing Compost or Using Compost to Produce B. *juncea* as Compared to Current Piggery Management Practices.

Net Cost	Marketing Composting*	Compost as Soil Amendment*
Added returns	60.05	191.75
Added Costs	- 92.00	91.86
Total $	- 37.25	+ 99.89

* Budgets were calculated for Farm Labor during One Month.

Benefits

Economic: Use of compost saves money due improved yields from a single application, less crop maintenance and watering

Environmental: Reduced pollution of piggery waste

Health: Possible reduction in incidence of leptospirosis from exposure to polluted water

Conclusions

- Increasing rate of swine manure compost significantly increased *B. juncea* yields at all rates of application and highest rate of compost application produced comparable results to chemical fertilizer

- Residual effect from a single compost application improved *B. juncea* yields in a second crop

- Swine manure compost is an effective slow release source of N, Ca & Mg as well as a liming agent. Compost is a viable alternative to imported chemical fertilizers

Conclusions

- With proper composting techniques, both compost recipes achieved and maintained elevated temperatures which converted hazardous animal waste into a presumed pathogen free soil resource

- Increasing N content of compost feedstocks results in a higher quality finished compost.
  - Fish by-catch is a promising source of Nitrogen for composting

- Compost production from piggery waste can provide net positive returns for a farmer when used as a soil amendment for food production
  - Composting is a viable solution to remove the waste introduction in the waste stream

Further Research & Application

- Research long term effects of swine manure compost application in Pohnpei soils for food production
- On site application and farmer based education on composting as a practice to manage piggery waste
- Public information to illustrate the connection between piggery waste, water quality, and leptospirosis
- Value of this project:
  - A step in integrating local farmers and scientific research to address the multifaceted issues currently facing Pohnpei

References

- Cooperband, L. R., Stone, A. G., Fryda, M. R., & Ravet, J. L. (2003). Relating compost measures of stability and maturity to plant growth. *Compost science & utilization*, *11*(2), 113-124.
- El Kader, N. A., Robin, P., Paillat, J. M., & Leterme, P. (2007). Turning, compacting and the addition of water as factors affecting gaseous emissions in farm manure composting. *Bioresource technology*, *98*(14), 2619-2628.
- Giles, P., Gavenda, R., & Franks, C. (2002). Influence of organic nutrients on soil quality in variable-charge soils, Pohnpei, Micronesia. In *17. World Congress of Soil Science, Bangkok (Thailand), 14-21 Aug 2002*.
- Golueke, Clarence G. *Composting: A Study of the Process and its Principles*. Rodale Press, 1973.
- Laird, W. E. (1982). Soil survey of island of Ponape, Federated States of Micronesia.
- Tiquia, S. M., Tam, N. F. Y., & Hodgkiss, I. J. (1996). Microbial activities during composting of spent pig-manure sawdust litter at different moisture contents. *Bioresource Technology*, *55*(3), 201-206
- Kuo, S., Ortiz-Escobar, M. E., Hue, N. V., & Hummel, R. L. (2004). Composting and compost utilization for agronomic and container crops. *Recent research developments in environmental biology*, *1*(Part II).

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Questions?