California State University, Chico
College of Agriculture

FINAL REPORT

CSU Chico, Foundation Project # ARI 69225: Creating value-added products from livestock waste and rice straw through in-vessel composting.

"Development of a commercial scale composting plant in Colusa County."

July 2002

SUBMITTED TO:
California Air Resources Board
Broken Box Ranch, Williams, CA
Applied Ag Research Initiative

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Beneficiary: Broken Box Ranch, Jerry and Sherry Maltby
Principal Research Investigator:
Cynthia A. Daley, Ph.D., Animal Science, College of Agriculture, CSU, Chico
Co-Investigator:
Andree Earley, Staff Research Associate, College of Agriculture, CSU, Chico
Dr. Pat Delwiche, Plant Pathologist, CSU Chico
Cooperators:
Logan Smith, Senior, Animal Science, College of Agriculture, CSU, Chico
Casey Cooley, Senior, Animal Science, College of Agriculture, CSU, Chico
Matt Claverie, Senior, Agriculture, College of Agriculture, CSU, Chico
Dr. Mitch Johns, Soil Scientist, CSU Chico
Dr. Jack Williams, UC Cooperative Extension
Industry Cooperators:
Broken Box Ranch, Williams, CA
Rice Straw Cooperative, Gridley, CA
California Air Resources Board

Goals and Objectives

The project was designed to develop a commercial-scale composting facility in Colusa County in an effort to convert rice straw into a "value-added" product suitable as a soil amendment or organic fertilizer. This was made possible through funding made available through the Air Resources Board to mitigate air quality concerns associated with the traditional practice of rice straw burning.

Burning has its benefits, i.e., it's inexpensive and effective in removing fungus, while replacing macro and micronutrients to the soil. However, burning also increased particulate matter in the air, thus alternative uses are being sought. Suitable alternatives should not compromise soil fertility nor should it enhance fungal pathogens. Compost production provides a very sustainable alternative to conventional burning practices, in that it builds soil profile, adds organic matter, nutrients and beneficial microorganisms to the soil. The feasibility depends greatly on the level of commitment by the grower.

Broken Box also proposed to develop a cattle back grounding facility that would use rice straw as feed in a variety of cattle rations. Considerable energy has been placed on this particular aspect of the project. Over the last 12 months, over 4,000 head have been fed in the facility. Current capacity is 3,000 head.

The ultimate goal of the project was to find low-cost, effective, end-use for rice straw.

Table 1. Summary of Rice Straw Use 2000 to 2002 by Broken Box

Use:	Total Tonnage:	Actual Material Cost:	Value-Added Product Price:	Net Return On Straw	Total Net:
1. Baled and sold as feed:	5,315 T	$16/T	$30/T	$14/T	$ 74,410
2. Straw fed to Broken Box	800 T	$16/T			
3. Feedlot rations	2,500 T	$16/T	$32.5/T	$16.5/T	$ 41,250
*Rations range from 50 - 100% rice straw and sold for $65/T					
4. Erosion control	50 T	$16/T	$30/T	$14/T	$ 700
5. Compost	1106 T	$16/T	$25/T	$ 9/T	$ 9,954
Total Straw	9,771 Tons				

Both the compost and rice straw feed require additional processing which will add cost to the product not reflected in this table.

Currently, the most profitable alternative for straw utilization at Broken Box is direct sales as baled straw for feed or as a part of a complete ration fed through the backgrounding lot. As the hay market drops, sales for baled rice straw (sold as feed) may also drop as customers look for better nutrient value for cattle supplementation. Thus, a diversified product line will be needed to withstand fluctuations in the commodity markets.

Overall, compost production at Broken Box has been slow due to the development and setup of other enterprises, as well as the current favorable cost/return on baled straw sold as feed. Details regarding each aspect of the business are as follows:

Enterprise Development:

1. **Feedlot Enterprise:** Currently, the feedlot has a one-time capacity of 3,000 head and employs 5 full-time employees, 2 seasonal employees, in addition to the owners, Jerry and Sherry Maltby. Over the last 12 months, the facility has fed over 4,000 head, consuming 2,500 tons of straw, approximately 1,250 lbs of straw/head.

The content of rice straw in the ration varies depending on the animal's nutritional needs. Rations have been formulated with straw content ranging from 50 to 100% with the remaining portion composed of tomato pumice and other byproducts. Byproducts are purchased on a contract basis, stored in bags or in commodity bays for use in least cost ration formulation.

The facility incorporates mounded dirt pens, separated by pipe and cable. Cattle are fed twice a day and have access to fresh water at all times. Capital investments include the loader, mixer/feed truck and the construction of the facility itself, i.e., pipe, cement, cable and labor. This enterprise has used 27% of the total rice straw consumed by the ranch during the startup phase of the project. Estimated rice straw utilization at the current 3,000 head capacity is approximately 4000 tons for 2002 – 2003. As utilization of the facility increases, so will the consumption of rice straw.

2. **Composting Enterprise**
The composting enterprise has been on the back burner with the development and expansion of the backgrounding lot. A composting surface was put in place in the spring of 2001 using road-base as the primary hardening material. Even with rollers and packing equipment, the base was not hard enough to run the large commercial scale Ag-Bag machine for the purposes of in-vessel composting. Without a firm surface, the machine bogs and cannot advance forward as the bag fills. Under these circumstances, lime stabilization or asphalt may be required to harden the surface. Lime stabilization has been shown to run about a 1/3 of the cost of cement or asphalt[1] and requires the incorporation of a combination of calcium oxide, cement, and fly ash.

As an alternative, large static piles or cribs were assembled last fall. Aeration tubes were placed at the base of each pile to force air throughout the crib (see photo). These static piles were allowed to compost all winter. In the spring of 2002, the cribs were disassembled and windrowed with a compost turner to improve compost texture. The material tested 1.4% N (primarily organic N), .4% P (phosphorus) and 1.1% K (potassium). A portion of this material has been used for marketing purposes in the form of a research trial to establish yield and soil fertility data (see section 4).

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[1] The Composters' Answers Book, Volume One. BioCycle. Journal of Composting & Organics Recycling. JG Press, Inc. Emmaus, Pennsylvania

Cost projections using real numbers generated from actual expenses show that optimal profitability can be achieved at 12,500 tons of production annually to offset the cost of equipment/pad and raw material charges. The project will need to invest in a compost turner and pad stabilization to stay on track with compost production projections. Table 1 shows the importance of scale to this particular component of the operation. One ton of straw is required for each ton of compost produced because of the reduction in mass, approximately 1000 pounds of manure is used/ ton of compost produced.

Seasonal composting can be accomplished on the road-base during the summer/fall months. Cribs will be used during the winter months. **The key component is moisture and proper aeration.** Without these components, the material will not heat up and breakdown into the humus-like material.

Table 2. Cost/Return on the composting facility with baling costs included.

Tons of Production	Labor $ Per T	Capital Costs Pad & Equipment cost/T	Raw Materials $16/ton baling costs	Manure $8/T (1/2 T per T Compost)	$cost/ton	$30/T Net Return
500	$1.51	$20.8	$16	$4	$42.31	-12.31
2500	$0.91	$4.16	$16	$4	$25.07	4.93
12500	$0.48	$0.832	$16	$4	$21.31	8.69
15000	$0.47	$0.69	$16	$4	$21.16	8.84

Labor was assessed at $14/hr and capital costs included pad stabilization and a large compost turner that was expensed over a five year period. The biggest cost associated with the compost is baling and rice straw removal from the field. If this is considered a cost of rice production, then the return on the bulk compost sales increases considerably.

Table 3. Cost/Return on the composting facility with baling costs excluded.

Tons of Production	Labor $ Per T	Capital Costs Pad & Equipment cost/T	Raw Materials $8/ton hauling	Manure $8/T (1/2 T per T Compost)	$cost/ton	$30/T Net Return
100	2.52	164	8	4	$178.52	100
500	1.51	32.8	8	4	$46.31	500
2500	0.91	6.56	8	4	$19.47	2500
12500	0.48	1.31	8	4	$13.79	12500

In addition, rice straw should be classified as grade 1, 2 and 3. Grade 1 straw is suitable for sale as feed off site to other producers at $30/Ton. Grade 2 straw is intermediate in quality for use in the feedlot, as the roughage component of the ration, assessed at $20/T. Grade 3 straw is poor quality straw that is damaged or left over from last year and not suitable for other purposes, assessed at $10/T. At this rate, the return on compost is $14.84/T and the composting process is adding value to this raw material.

Potential for straw utilization is 15,000 T/yr when equipment and capital costs are used optimally.

3. **Marketing Research:**

Identifying Competition: The primary competitors to bulk compost sales are chicken and turkey manure/litter at $42/ton spread on the field, this material is considered a "better" buy based on total N values for growers looking for organic fertilizers. Nutrient analysis of turkey manure ranged from 1.8 to 2.8 % nitrogen, of which 3,500 ppm is ammonium-N, an ionized form of nitrogen that is readily lost from the soil. A winter forage trial was recently conducted to assess forage productivity between compost and turkey manure (see research update section 4).

Bulk compost would cost $44/ton spread on the field ($30/T for material, $14/T hauling and spreading costs). Compost would run about $31.4/ pound of nitrogen as compared to $17.5/pound of nitrogen for Turkey manure. Compost is more expensive to use as a fertilizer, albeit a better product in terms of its quality as a soil enhancer. ***To be competitive with raw turkey manure, we will have to enhance the % N or decrease the cost/ton.*** Broken Box is currently looking at tomato waste as an additional source of nitrogen that may be used to enhance the level of organic nitrogen in the compost without increasing soluble salt concentration. See research update section 4.

Alternatively, end-users of compost could be educated as to the benefits of compost over raw manure products. Growers need to look beyond total N and look at the quality of N. Additional benefits include:

1. Compost is weed seed free (due to heating process)
2. Compost is pathogen free (due to heating process)
3. Compost contains predominately fixed nitrogen (nonleachable)
4. Compost contains both macro and micro nutrients
5. Compost contains beneficial micro-organisms that enhance soil fertility
6. Compost builds soil structure

Compost is weed-seed free and pathogen free, thus there is no concern with pathogen transfer to fruit or vegetable crops as may be possible with raw manure products like chicken or turkey manure. In fact, a recent report from the U.S. Food and Drug Administration and Health Canada records indicates that the organic market has a significantly higher recall and warning rates than conventional foods due to potentially dangerous allergenic ingredients, bacterial contamination and other serious safety-related concerns, a portion of which may be related to the raw organic materials used to fertilize and grow organic crops.[2]

Compost is also rich in organic matter and beneficial microorganisms that enhance soil fertility and suppress soil pathogens (see research update section 4). Several scientists have demonstrated the beneficial effects of manure-based composts as biocontrol for soil borne plant pathogens. For example, Hadar and Mandelbaum (1992) determined that media amended with manure based compost was suppressive to soil born pathogens such as *Rhizocotonia solani and Pythium aphanidermatum*.[3] There are many others who have shown suppression of a full range of plant fungus, further justifying the use of composted organics as the intelligent alternative to raw manure products.

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[2] General recall and food warning data: http://www.safetyalerts.com; http://www.foodhaccp.com; Canadian Food Inspection Agency (Health Canada) product recalls and food warnings can be found at : http://www.inspection.gc.ca/english/corpaffr/recarapp.recaltoce.shtml; U.S. Food and Drug Adminsitration product recalls and food warnings ca be found at: http://www.fda.gov/oc/po/firmrecalls/archive.html

[3] Y.Hadar and R. Mandelbaum. 1992. Suppressive Compost for Biocontrol of Soil borne Plant Pathogens. Phytoparasitica 10: Suppl. 1992.

Marketing Surveys: The University recently conducted a mass mailing to California Certified Organic Farmers (CCOF) in the Butte County area to assess interest in a compost product that was competitively priced at $20/ton FOB. With over 80 mailings, 10 responses (12% response rate) were received and the sale of 50 tons was complete in 14 days.

We found that most growers needed trucking and spreading services.

Phone surveys were recently conducted to determine local compost needs and marketability to both Organic growers and Nursery/Landscape suppliers. The results are as follows:

Organic Growers Survey:

1. What crops are you currently growing? (% of growers contacted)
   Rice: 25 % Walnuts: 12.5% Tomatoes: 9.4% Melons 9.4% Prunes: 6.25%
   Oranges: 6.25% Oats: 3% Cherries: 3% Apples: 3% Corn 6.25%
   Veggies: 3% Other: 13%

2. What are you currently using as a fertilizer?
   Chicken/turkey: 28% Manure: 20% Feather meal: 7% Compost: 30%
   Fish Emulsion: 5% Nothing: 4% Other: 6%

3. What determines which product you will use?
   Price: 30% Organic Rules: 30% Soil Test: 20% Neighbor: 10% Advisor: 10%

4. What are you currently paying for this product? Highly variable from respondents. $10/yd to $40/ton delivered

5. Do you require trucking/spreading services? What is it worth?
   75% required trucking and/or spreading services
   25% had their own truck
   What the grower felt it was worth varied greatly.

Nursery/Landscape Survey:

1. Do you sell compost? What type?
   Yes: 80% No: 20%
   Chicken Manure: 30% Green Waste: 30% Fir compost: 15% Ag Waste: 10%
   Mulch: 15%

2. Easy/Hard to sell? (1 easy to 5 difficult)
   1 – 2 easy to sell: 67% 3 – 4: 30%

3. Primary markets? 50% to homeowners
   50% to landscaping businesses

4. Price paid? Majority is $25- $30 / yard retail.

5. What specific things are your customers looking for?
   A very clean product; consistent; loosening agent to break up clay soils; pH; high organic matter.

Marketing Plan: The survey data tells us that most organic growers are small and require hauling and spreading services. Nitrogen is the most important component within the material, this value, coupled with price and service will determine which product they will purchase.

The survey data also shows that the nursery market may be more suitable for this particular product than the CCOF market. The compost produced from rice straw is consistent, weed seed free and very high in organic matter. Our survey data is consistent with Compost Marketing and Labeling Project produced by Cornell Waste Management Institute, Woods End Research Lab, NYS Organic Recycling and Compost Council and the NYS Energy Research and Development Authority in 2001. In this report, CWMI indicated that biggest end-user of compost was Nursery/Greenhouse businesses, Vegetable/Fruit and Flower growers, Home Gardeners and Landscapers. For profit businesses tended to by it in bulk, where the home gardeners bought the compost by the bag, paying $2 - $4 / cubic foot. The predominant desirable characteristics sought in a compost product are consistency and a product free of chemical contaminants and weed seeds. Nitrogen is not even mentioned in the CWMI data.

The following items have been completed to enhance the marketability of Broken Box Compost:

1. Market survey work and market priority identification
2. Active website up and running
3. Brochure development
4. OMRI certification
5. Multiple research trials to determine quality, productivity and safety of the material.

4. Composting research:

The University Farm at California State University Chico has developed a site that is now producing 250 tons of compost from dairy manure and rice straw annually using conventional windrow methods primarily for research purposes to support the commercialization of Broken Box Compost. The following studies have been conducted:

1. Compost quality assessment
   i. Crop productivity
   ii. Phytotoxcity
2. Economic evaluation of windrow vs. in-vessel
3. Plant pathogen suppression

- **Compost Quality**

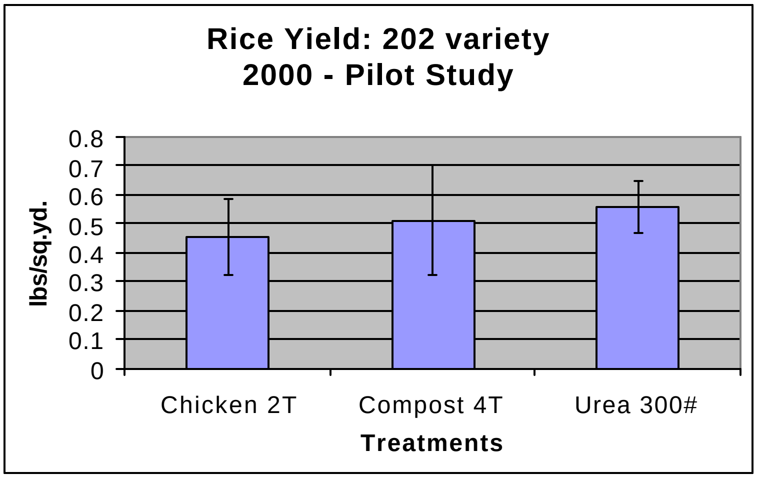
Nutrient Composition: NPK: 1.2: 0.5: 1.5 as an average value
Approximately 30% is Organic Matter
pH is 8
Fecal coliforms: 0 counts
E. coli: 0 counts
Salmonella: 0 counts
Heavy metals: Arsenic, Lead and Mercury all negative.

- **Crop Productivity**.

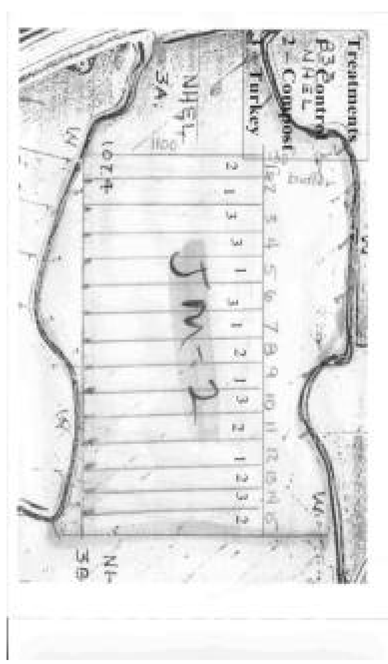
Rice Productivity Study: A pilot study was recently completed in the summer of 2000 to determine the effect of compost on plant toxicity, soil fertility and rice productivity. The study focused on a 22-acre plot in Williams, California, an area that has been used primarily for rice production in the Sacramento Valley.

The test site was divided into plots and treated with the following: 1) Compost @ 4 tons/acre; 2) Chicken manure @ 2 tons/acre; and 3) Urea at 300#/acre. The amount of fertilizer was calculated for a standard N. Each treatment was replicated 3 times and harvested in 18' X 350' strips for analysis of total rice yield /square yard. Both chicken and compost was applied via flail wagon application, urea was flown on with an applicator plane.

The rice was harvested in November of 2000 using conventional methods. Each 18' X 350' strip was weighed using a mechanized weigh wagon.



Urea produced the most consistent yield as shown by the narrow standard deviation, although there were no statistical differences between plots in total yield.

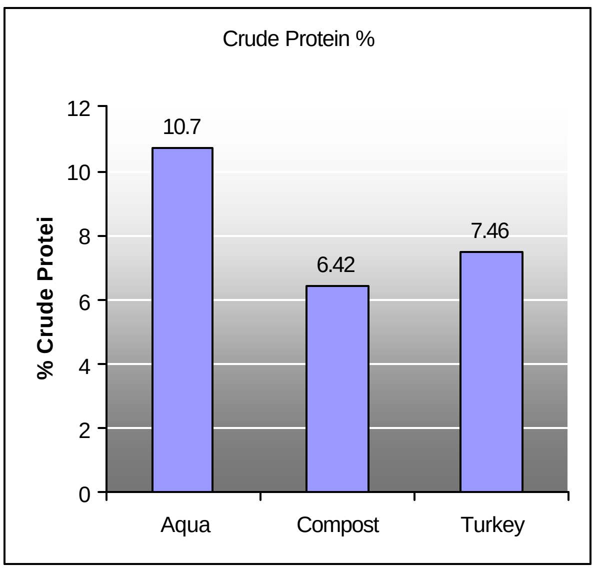


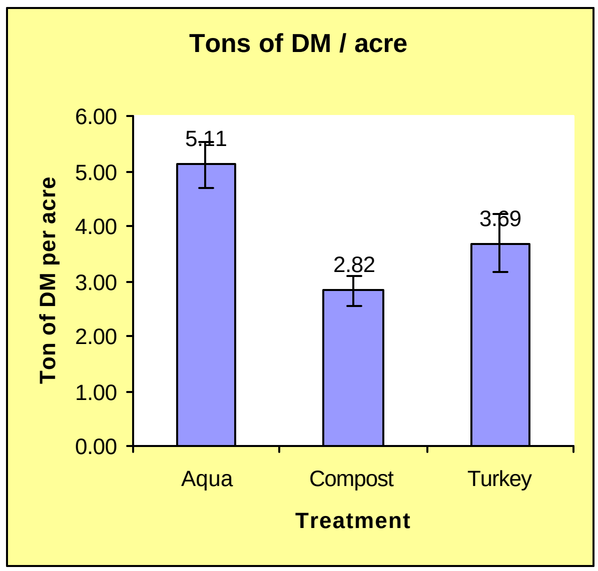
Winter Forage Trial: A winter forage trial was conducted in the fall of 2001, designed to compare compost with its major competitor for the organic growers market, turkey manure. As a positive control, a third treatment implemented anhydrous nitrogen at 140 units/acre. All other treatments were standardized to similar

N concentrations. Applications of turkey manure reached 4 T/acre, while compost was applied at 6T/acre to achieve comparable N values. Each treatment was replicated 5 times and covered roughly 3 acres/plot.

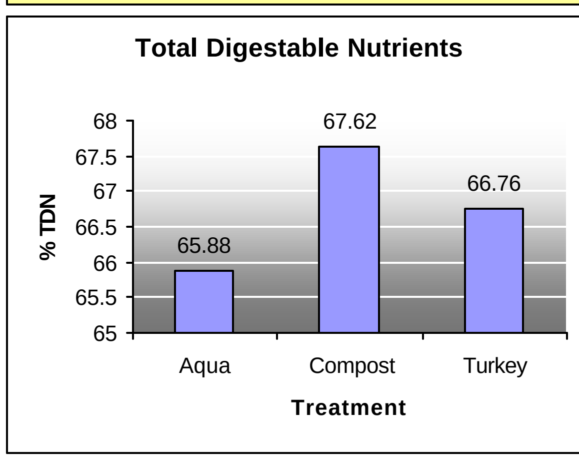
Each test plot was swathed/chopped and weighed separately generating tonnage values for each replicate. Special thanks to Dan Luis for his cooperation and generous donation of time, equipment and energy.

At constant N, the inorganic fertilizer produced 5 ton to the acre while turkey and compost produced roughly 3.5 and 3 tons/acre, respectively. As expected, the plant material also tested higher for crude protein content as compared to either turkey or compost treated crops. Turkey had a slight advantage over compost in both overall tonnage and crude protein content within the plant material.





However, the organic fertilizers contained higher TDN (total digestible nutrients) values than aqua treated forage, suggesting that the overall nutrient content may be enhanced by organic fertilizers.



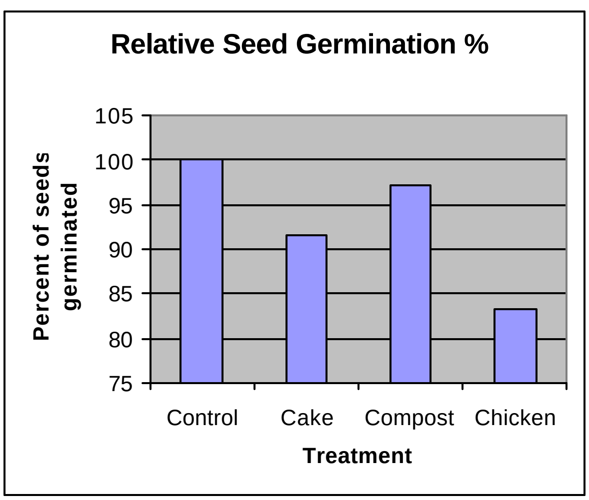
Compost tends to demineralize slower, releasing N over time, thus reducing the amount of leachable N in the soil.   Indeed, post harvest soil analysis indicates that the aqua treated soil contained significantly higher NO_3 levels than the composted treatment, leaving the possibility for nitrate leaching into ground water. The real benefit of compost becomes reality in year 2 or 3 of consistent use, at that point in time, there is enough organic N demineralizing to supply the crop with adequate N for optimal growth and yield.

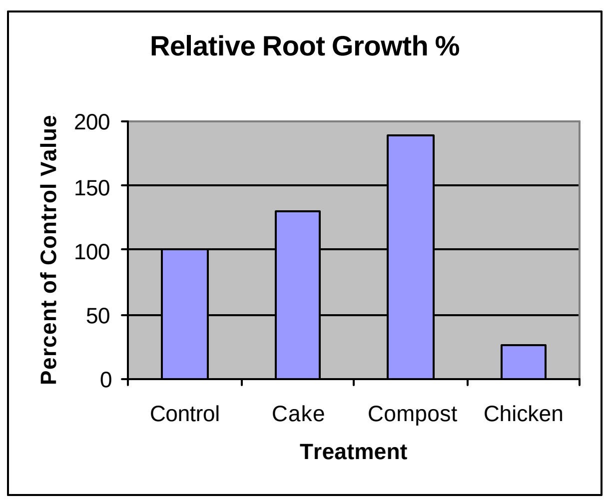
- **Plant Phytotoxcity Index:** As with any new product, it is important that the material does no harm. Two separate assays were conducted to determine if plant toxicities existed. Seeds were germinated in compost extract to determine the rate of seed germination and rate of growth as compared to chicken litter, compressed pig manure and an untreated control.

Compost treated seeds germinated at a similar rate to the untreated controls. Both raw manure products inhibited seed germination, with chicken manure extract producing the most severe reduction.

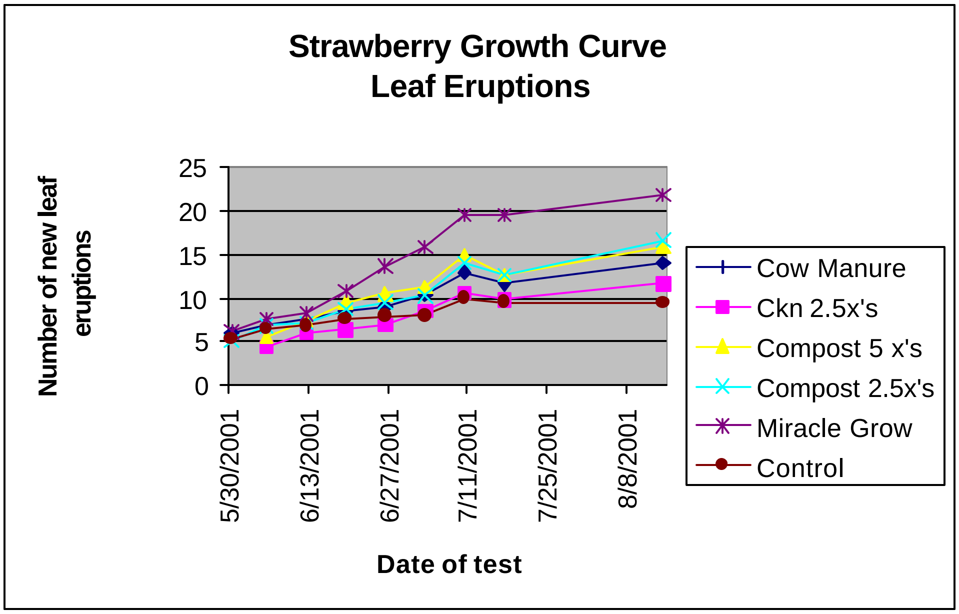
Relative root growth was also stunted by raw chicken manure, as demonstrated in both the photo to the right and the graph below. Compost, on the other hand, stimulated significant root growth.

These data suggest that compost is superior to chicken manure in the critical areas of seed germination and seedling growth.





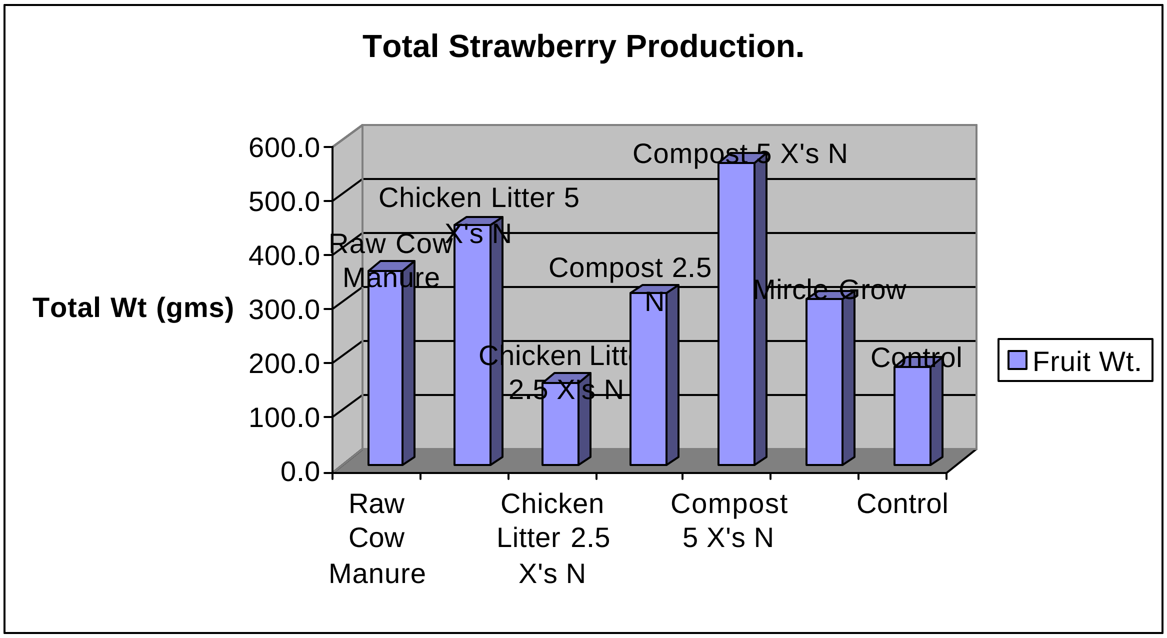
- **Vegetable Crop Applications**: Compost was also tested under greenhouse conditions as a fertilizing agent for strawberry production. For this particular study, strawberry seedlings were obtained and planted in ½gallon containers containing a peat moss based soil mix. Fertilizer was added to each pot according to a standard quantity of N. Again, the fertilizers compared were raw cow manure, chicken litter, compost and both a positive (miracle grow) and a negative control (no fertilization). All plants were monitored for leaf eruptions over time as well as fruit productivity.



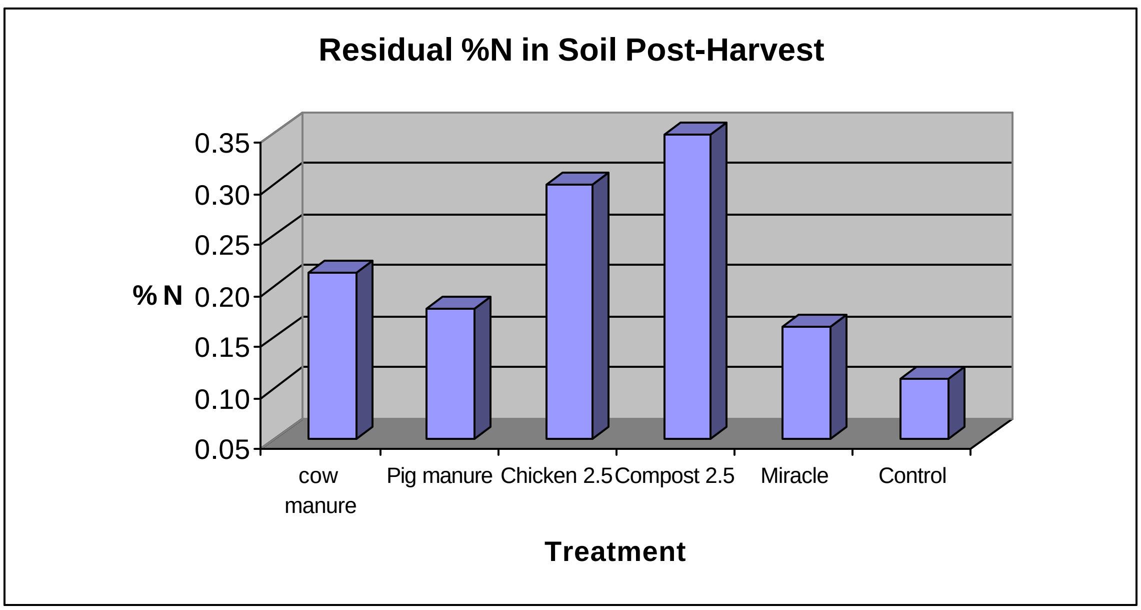
Both chicken manure and compost had a considerable portion of total N in the organic form. To accommodate the slow rate of demineralization, chicken manure and compost was added at 2.5 X's N. At present, it is not known what the exact rate of demineralization is for the various organic compounds, so we also included a 5X's N treatment group to accommodate the possibility of a 20% demineralization rate.

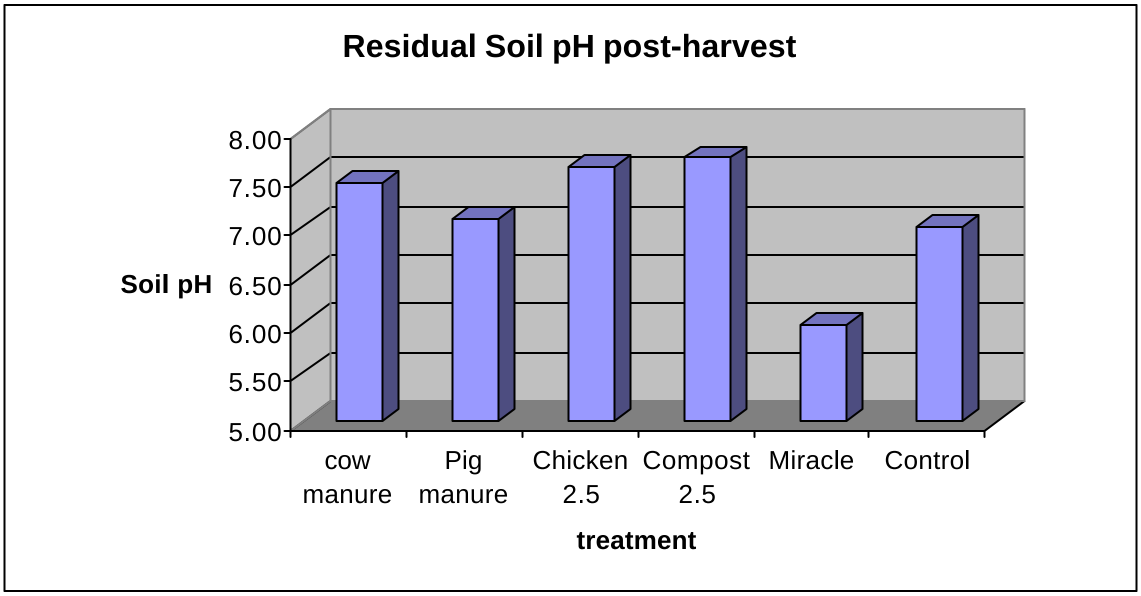
Miracle Grow produced the leafiest growth and the most lush looking strawberry plants, however, it did not produce the most fruit. 5X's compost produced the most fruit while stimulating a more moderate amount of green leaf growth.

Chicken manure tended to burn the plants at higher concentrations, i.e., 5X's N. Those plants tended to be stunted early on and then seemed to compensate following recovery.



Post Harvest Soil Conditions: Soil samples were collected post-harvest to determine if in fact, compost leaves behind nitrogen stores for the next crop. Indeed, the compost treated soils contained the highest total N, with the lowest NO_3 ppm (leachable N) of any treatment, although not statistically different from it's leading competitor, chicken manure. In addition, soil pH was also affected by fertilizer regime; organic fertilizers maintained a more favorable pH than the inorganic treatment, i.e., Miracle Grow. Ideal soil pH would be considered greater than 7, miracle grow reduced post-harvest soil pH by roughly 15%.





Plant Pathogen Suppression: Manure based composts have been shown to inhibit soil borne plant pathogens, particularly fungal organisms. We felt it was important to determine if rice straw compost possessed pathogen-suppressing capabilities. Certainly this would be of significant benefit to growers and add value to the marketability of this material.

This particular study was completed in cooperation with Dr. Patricia Delwiche, Plant Pathologist, California State University, Chico and Summer White, student intern. Dr. Delwiche has worked with a variety of fungal organisms and felt that watermelons would provide an appropriate test for the soil suppressing nature of the compost. The fungus used in this experiment is called *Fusarium*, an organism that lives in infected soils, causing leaf wilt in a variety of vegetable crops across the country.

To test this hypothesis, watermelon seedlings were germinated and tap roots clipped to mimic root tip damage, thus compromising the seedling prior to exposure to the *Fusarium* inoculation. Approximately 20 seedlings were allotted to one of eight treatments.

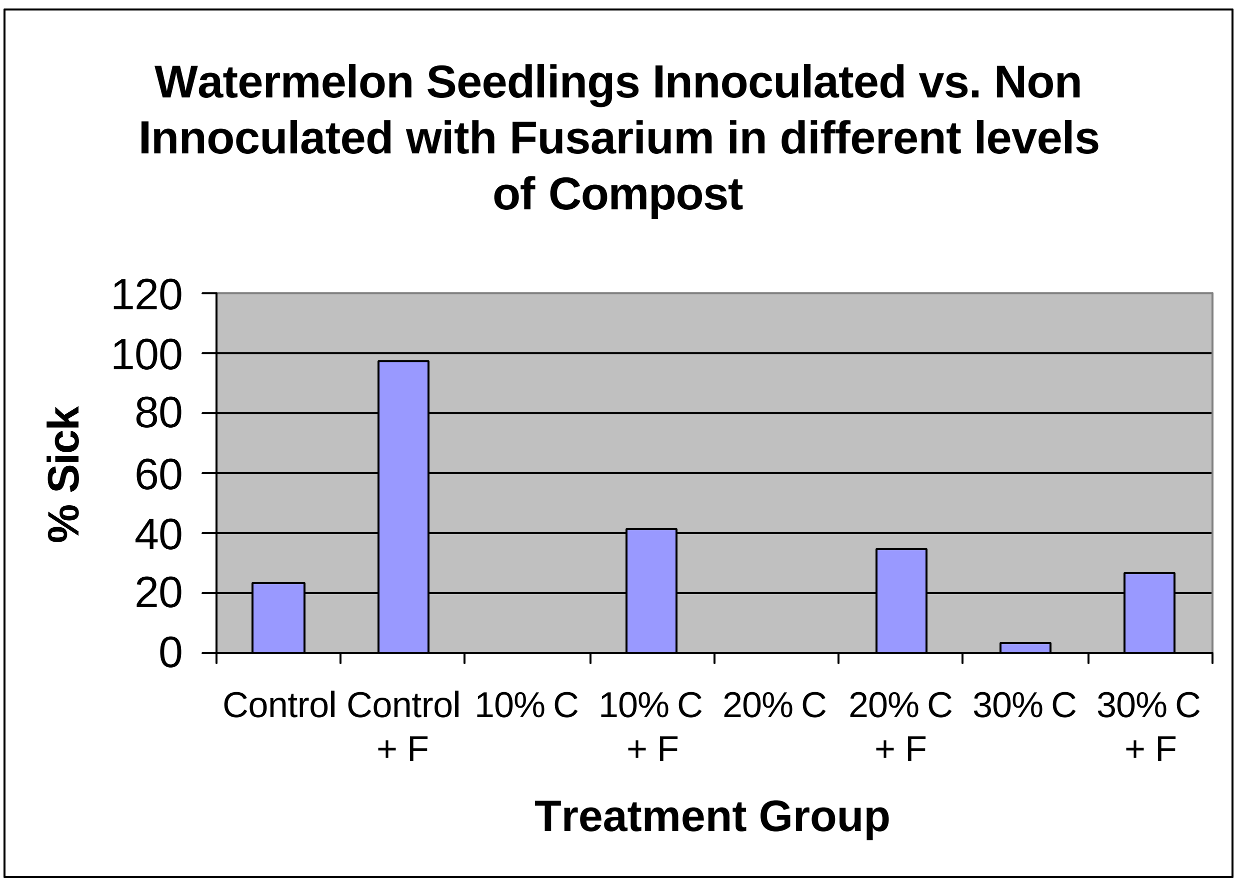
Treatments included:

1. Control, non – inoculated (NI)
2. Control, inoculated (I)
3. 10% compost, NI
4. 10% compost, I
5. 20% compost, NI
6. 20% compost, I
7. 30% compost, NI
8. 30% compost, I

Seedlings from treatments 2, 4, 6 and 8 were bathed in *Fusarium* inoculum prior to planting, providing a complete exposure to the fungus.

Each treatment contained 24 seedlings, which were monitored daily for signs of disease. After 3 weeks, the data was compiled and is summarized in the following graph. Non-inoculated control plants were slightly cross contaminated, developing a 20 % incidence of *Fusarium*-like symptoms. As expected, 100% of the control inoculated seedlings developed symptoms.

Seedlings treated with 10% compost demonstrated 40% sickness, a 60% reduction as compared to the inoculated controls. There was a slight increase in the % suppression as the concentration of compost increased in the soil mix. Thus, our data suggests that rice straw compost has soil pathogen suppressing capabilities that enhance plant health and productivity.



Conclusions:

Compost production from rice straw and dairy manure is feasible and can be profitable under the right management scenario. The marketability outlook for this product is excellent and will continue to grow as the organic movement continues to gain momentum in the U.S. and as air and water quality laws continue to strengthen and become enforced..

Any dairy with 300 or more dairy cows produces enough cow manure to offset the cost of composting equipment. These types of dairies are in an excellent position to work with local rice growers in a cooperative arrangement.

Both air and water quality laws and regulations will continue to limit the application of raw manures, thus compost will provide a low cost, easy alternative, as a soil conditioner that is weed seed and pathogen free.

Assessing the real value added to manure and straw from this process is difficult, in lieu of the economic figures to accurately assess the benefit of full compliance with state air and water quality laws. Perhaps, on average, the typical dairy is in violation once or twice in a lifetime for example, the cost of that fine and required modifications to the existing facilities for compliance purposes is of significant value.

The question on everyone's mind is "What is it worth to do the right thing?", i.e., never leach contaminants into the ground water and never blow particulate matter into the atmosphere? These are values that do not have a readily available price tag, and therefore d////ifficult to factor into the profitability equation.

Recommendations for Broken Box:

1. Harden existing surface with fly ash and cement for windrow compost production
2. Develop crib structures for static pile aeration during winter months
3. Purchase turner for 12 month compost production
4. Develop water source for easy access to windrows for proper moisture maintenance.
5. Explore bagging options to increase product value and enhance marketability.
6. Maintain website
7. Advertise in CCOF website.
8. Develop relationship with local nurseries and landscapers for ongoing contracts.
9. If compost production begins to take off, hire sales staff to move product

Respectfully Submitted:

_______________________________________ Date: ___________________________________

Cynthia A. Daley, Ph.D.
College of Agriculture
California State University, Chico
Chico, CA 95929