LONG TERM EFFECTS OF DAIRY COMPOST ON CROP PRODUCTION AND SOIL QUALITY

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The dairy industry in the Magic Valley area of southern Idaho has rapidly expanded since 1990. Manure can be a valuable resource material in crop production systems without a negative environmental impact if properly managed. One impediment to its use is high hauling costs, particularly since fresh manure which can contain up to 80% by liquid by weight. The weight problem can be reduced by composting or drying. Composting is achieved by using aerobic microorganisms to decompose organic materials into more stable forms. Compost as an end product is a humus-like material that can provide nutrients, organic matter, and other soil improving qualities. The volume and weight of compost are generally reduced 30 to 60% for the starting material. Compost contains less N than raw manure and it is in a different form. The mobile nutrients in compost are more stable and less likely to contribute to environmental pollution through leaching or runoff losses. Southern Idaho soils are low in soil organic matter and may benefit from compost additions. There is very little information in southern Idaho regarding the use and management of compost material for crop production including its effect on the soil physical and chemical properties. Identification of the optimum application rate and its effect on soil physical and chemical characteristics may facilitate the use of this resource by producers. The objectives of this four-year study were to determine the optimum economic, agronomic, and environmental compost application rates for sustainable irrigated crop production in southern Idaho.

MATERIALS AND METHODS

A four-year field study was initiated in 1996 on an irrigated, Portneuf silt loam soil on a cooperator's field near Kimberly. The crop rotation was sweet corn seed, potatoes, malting barley, and sugarbeets. Dry beans were grown on the experimental site in 1995. The study was surface irrigated the first year of the study but was sprinkler irrigated with a solid set system in 1997 and with a center pivot in 1998 and 1999, with the corners irrigated by solid set. All cultural practices, including irrigation amounts and scheduling, were controlled by the producer. Commercial fertilizer was not applied on the study site, except for a N variable started in 1997 to achieve optimum production.

The concept of the study was to evaluate an initial compost application rate to 'jump start' the soil-plant-water system and to then determine the yearly application rate needed to maintain the system for optimum crop production. The experimental design was a completely randomized block with the treatments arranged as split-split blocks. The initial compost applications were the main blocks, which were further split for the yearly

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applications, which in turn were split for the N fertilizer variable. The experiment contained four replications. All data were analyzed with the SAS statistical package.

Initial compost rates of 0, 2.5, 5, 10, and 20 tons/acre were applied in the spring of 1996 before preplant tillage operations. Yearly compost rates of 0, 2.5, and 5 tons/acre were applied in the fall fo 1996, 1997, and 1998. All compost applications were applied on an oven-dried weight basis with commercial application equipment and incorporated by disking or plowing. A subsample of compost was taken from each truck load at the time of application for chemical analysis. The N fertilizer (urea) was applied at a single, recommended rate at the optimum time(s) for each specific crop. If applied to the growing crop, it was immediately followed with an irrigation.

Nutrient uptake was monitored during each growing season by sampling whole plants two or three times. Standard plant tissue samples for nutritional monitoring were also obtained generally at the same time as the whole plant samples. Final crop yields were determined with plot or commercial harvesting equipment at the appropriate time for each crop. Economic analysis was performed using current cost information for inputs and crop market value and quality incentives.

Initial soil samples from each block and subsequent samples from each plot were taken in 12-inch increments to two feet in the spring of each year before tillage and any fertilizer applications. Standard soil tests were performed on these samples, including a laboratory estimate of N mineralization. The buried plastic bag technique was used to estimate N mineralization under field conditions by installing 18-inch bags shortly after planting the respective crop. Additional soil characteristics measured at the midpoint and at the end of the study included water holding capacity, infiltration rate, cation exchange capacity, biological activities, aggregate stability, and compaction.

RESULTS AND DISCUSSION

Compost Characteristics

As delivered the compost contained the range of nutrients shown in Table 1. These are for samples taken from the four field applications. The mineralizable N values are those determined in a laboratory incubation procedure. Average amounts of nutrients per ton of compost only reflect the total amount in the compost and not plant-available nutrients. Approximately 80 lbs P/A, 190 lbs K/A, and smaller amounts of micronutrients could be added by applying 10 ton/A of compost.

Table 1. Nutrient concentrations of dairy manure compost on a dry weight basis.

Property	Range	Average/ton
Water, %	20-30	---
Total N, %	0.7-1.45	20 lbs
Phosphorus, %	0.33-0.40	8 lbs
Potassium, %	0.93-2.04	19 lbs
Calcium, %	1.36-2.61	27 lbs
Magnesium, %	0.54-0.95	11 lbs
Sulfur, %	0.31-0.75	6 lbs
Sodium, %	0.25-0.52	6 lbs
Zinc, ppm	69-171	0.1 lb
Iron, ppm	8500-10500	17 lbs
Manganese, ppm	180-400	0.4 lb
Copper, ppm	20-530	0.04 lb
Boron, ppm	10-40	0.05 lb
Molybdenum, ppm	8-77	0.02 lb
Nitrate-N, ppm	500-900	1.5 lbs
Ammonium-N, ppm	8-27	0.03 lb
Mineralizable N, ppm	300-500	0.8 lb

N Mineralization

Part of the benefit from a compost application will be from additional N released as the compost is mineralized. The mineralized N increased as the compost application rate increased (Figure 1) during the growing season in which the compost was applied. An average of about 10 lbs N was mineralized between April 1 through September 12 from each ton of compost applied. This combined with the initial NO_3-N and NH_4-N in compost provided 12 to 15 lbs N/ton for plant growth the year of application.

Sweet Corn Seed Yields – 1996

The spring 1996 soil tests for P (25 ppm), K (180), and Zn (3.1 ppm) were apparently sufficient for crop yields as there was no response to any of the compost rates (Table 2). Since there was no significant response to compost it would appear that N availability was not a limiting factor either. The top two feet of soil contained approximately 120 lbs N/A as NO_3-N and NH_4-N before planting (April 4). There was also more than 180 lbs N/A mineralized where no compost was applied (Figure 1). No fertilizer N was applied to the sweet corn crop.

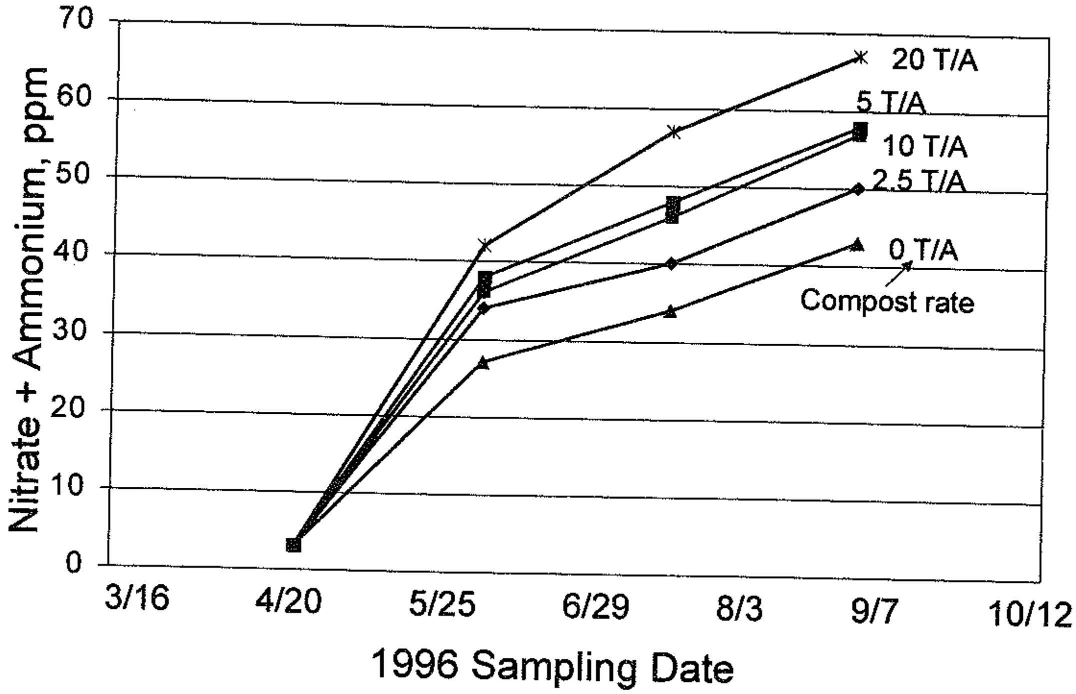

Figure 1. Effect of diary compost rate on N mineralization in buried plastic bags under 1996 field conditions.

Table 2. Effect of compost rate on sweet corn seed yields, 1996. (n.s. = nonsignificant effect @ Pr>0.10)

Compost Rate	Total Seed Yield	Clean Seed Yield
tons/A	lbs/A	lbs/A
0	3664	2932
2.5	3743	2994
5	3689	2951
10	3640	2912
20	3703	2963
	n.s.	n.s.

Potato Yields and Quality – 1997

Russet Burbank potatoes were planted in 1997. A significant yield response occurred from N (150 lbs N/A) applied during tuber growth. Main effects from the initial 1996 compost applications were not significant for any measured yield parameter. High initial compost rates (10-20 ton/A) tended to reduce N and yearly compost application effects (Data not shown). The N and yearly compost effect will be discussed at only the zero initial compost rate to separate effects (Table 3). Compost tended to increase yields, particularly at the 5-ton rate in the absence of N application. In the presence of N, highest yields were obtained at either the 2.5 or 5 ton/A compost rate.

Table 3. Effect of N and yearly compost on potato yields, quality, and profit at the zero initial compost rate.

Yearly Compost ton/A	N rate lb/A	Yields cwt/A	Tubers % ones	Tubers %>10 oz	Specific Gravity	Adjusted Net $/A	Profit $/A
0	0	469	83.4	28.3	1.089	2189.72	---
2.5	0	474	86.1	24.2	1.088	2074.49	(115.24)
5	0	518	85.4	27.3	1.089	2215.06	25.34
0	150	513	83.2	37.3	1.086	2250.61	60.89
2.5	150	528	90.2	36.9	1.082	2315.22	125.49
5	150	529	85.9	37.3	1.083	2335.87	146.15
Source		Pr > F	Pr > F	Pr > F	Pr > F	Pr > F	---
Yr Compost		0.6713	0.1627	0.6917	0.0045	0.1896	---
N rate		0.0002	0.7494	0.0001	0.0001	0.0450	---
Yr * N		0.0277	0.6273	0.6875	0.6076	0.4589	---

Tuber yields increased from 469 cwt/A to 529 cwt/A when 5 ton/A of compost was applied the previous fall and 150 lbs N/A were applied during tuber growth. Yield with N fertilizer application and no compost was 513 cwt/A, while yield from the 5 ton/A compost treatment without N fertilizer was 518 cwt/A. Tuber quality parameters were generally high. Percentage large tubers (>10 oz) were increased by the N application. Highest specific gravity occurred where compost was applied without N fertilizer, but applications of N fertilizer and compost together reduced specific gravity. There was a tendency for compost treatments (Table 3). There was no effect of compost on internal tuber quality parameters (hollow heart, brown center, and brown spot). Nitrogen decreased the incidence of hollow heart from 7% to 4% (Pr<0.05).

Net dollar returns were estimated by assuming the potato price @$5.00/cwt, N fertilizer @$0.35/lb, and compost @$20.00/ton delivered and spread. Price adjustments were also made for the percentage of number-one tubers above 50%, the percentage of 10 oz tubers above 11%, and for specific gravities higher than 1.077. Without any N fertilizer there was only a $25.34 per acre profit at the highest yearly compost rate, while adding N fertilizer to the 5 ton/A compost rate increase returns $146.15 per acre. The application of only N fertilizer without compost returned $60.89 per acre.

There was also a positive effect of compost during the second cropping year after application. Tuber yields in 1997 were 503 and 533 cwt/A where 10 and 20 ton/A had been applied in April 1996, respectively. The addition of N fertilizer increased the tuber yields at only the lower initial rates, i.e. 2.5 and 5 ton/A.

Malting Barley Yields and Quality – 1998

Coors malting barley was grown in 1998. An application of Cerone was not made to prevent lodging. There was a significant response to N fertilizer (60 lbs/A, applied preplant) and a significant N*yearly compost interaction for yields, screenings, protein concentration, and net returns (Table 4). There was no significant main effect of the intial compost appliation made in April 1996 nor was there any significant interaction involving either N or yearly application on any independent variable (Data not shown). Data from the N and yearly compost applications at the zero initial compost rate were similar to those shown in Table 4, although the highest yield in the experiment was 6680 lbs/A for the 60 lb N/acre and 5 ton/A yearly compost treatment with no initial compost.

Table 4. Effect of N and yearly compost on malt barley yields, quality, and profit across all initial compost rates.

Yearly Compost ton/A	N rate lbs/A	Yields lbs/A	Test Weight lbs/bus	Screen %	Protein %	Adjusted Net $	Profit $
0	0	4387	50.0	8.2	11.95	299.45	---
2.5	0	5221	50.8	7.8	11.68	277.47	(21.98)
5	0	4792	50.7	7.8	11.85	256.58	(42.87)
0	60	6053	50.6	14.5	11.98	386.28	86.83
2.5	60	5951	50.0	19.9	12.00	349.38	49.93
5	60	6189	50.4	14.9	11.95	247.20	(52.25)
Source		Pr > F	Pr > F	Pr > F	Pr > F	Pr > F	---
Yr Compost		0.0146	0.5860	0.0432	0.2901	0.0001	---
N rate		0.0001	0.1354	0.0001	0.0033	0.0001	---
Yr * N		0.0001	0.0001	0.0146	0.0501	0.0001	---

Net returns were calculated using a base of $6.70 per cwt if the barley met the quality parameters and $4.50 per cwt if it did not. If screenings exceeded 25%, the barley was rejected for malting purposes, while less than 11% screenings received a $0.03 per cwt incentive per percentage point. Other costs were $0.25/lb N and compost @$20.00/ton delivered and spread. In this study both color and protein were acceptable for malting purposes in all treatments. The application of compost without N lost money at both the 2.5 and 5 ton/A rate (Table 4). Nitrogen increased net profit $86.83 per acre on an investment of $15.00 per acre, while N and the 2.5 ton/A compost rate returned $49.93 per acre. It is not known if part of the negative effect from the N and higher compost rate together was from the lodging that occurred.

Sugarbeet Yields and Quality

Sugarbeets were planted in the research plots in the spring of 1999. The recommended N fertilizer rate used in the study was 200 lb N/acre based on the U of I and the sugarbeet growers guidebook. The low N rate used was 100 lb N/A. Plant stand counts for the low N (100 lb N/A) treatment plots averaged 160/100 ft, while those for the high N (200 lb N/A) treatment plots averaged only 120/100 ft. Stands in the 200 lb N/A treatment plots were not uniform, which may have reduced overall root yield potential. The field was irrigated with an overhead irrigation system according to the grower's scheduling program.

The major compost response in the sugarbeet study was related to the annual compost application rate at the 100 lb N/A fertilizer rate. Annual applications of 2.5 ton/A produced the highest root and sucrose yields and the highest net economic return per acre. The 200 lb N/A rate reduced sugarbeet yields overall compared to the 100 lb N/A rate, possibly due in part to the lower, less uniform plant stands in the high N plots. There were no residual effects of the initial 1996 compost application treatments on root or sucrose yields. Brei nitrates were not significantly affected by annual compost rates, but brei conductivity increased at the 5 ton/A rate. The growers yield on the field area surrounding the research plots was 35 tons/A with 17% sucrose.

Other Information

Soil samples taken after crop production in 1996 and 1997 had low NO_3-N and NH_4-N concentrations (<3-5 ppm). No apparent differences occurred between treatments. This indicates that the crop removed essentially all the N available during the growing season. Under this condition the potential for residual NO_3-N leaching during the non-cropping portion of the calendar year is small.

Infiltration data using a single ring infiltrometer were obtained in late summer of 1997 from all combinations of compost treatments except for the initial 2.5 ton/A compost rate. There were no statistically significant differences between treatments for total water volume infiltrated or steady state infiltration rate. There was a trend for the highest compost rate to have a slightly higher infiltration rate than where no compost was applied.

The soil organic matter from selected compost treatments in the preplant spring 1997 soil samples was fractionated into nonpolar (fats, oils, and waxes), hemicellulose, lignin, cellulose, starch, and sugar compounds. There were no significant treatment differences for the relative distribution of these fractions, but the relative amount of cellulose, starch, and sugars compounds tended to increase at the higher compost rates (Data not shown). Sustained applications (15-20 years) may be necessary to show benefits from the lower application rates (2-3 tons/A-year).

SUMMARY

Progress to date indicates that a two to three ton application of dairy manure compost combined with a normal fertilization program can benefit crop production, particularly for high cash value crops like potatoes and sugarbeets. The N fertilization rate can be reduced compared with an application without compost. Residual crop yield benefits were only apparent when 10 to 20 tons of compost were applied the previous year. No residual benefits were observed from any rate in the third cropping year.

Soil testing data suggest that compost applications will not enhance environmental degradation from NO_3-N leaching losses after cropping. If the surface runoff is not controlled, there may be sediment and associated nutrient losses. Attempts to measure improvements in soil physical properties or changes in soil organic matter characteristics were not successful after two years of compost application.

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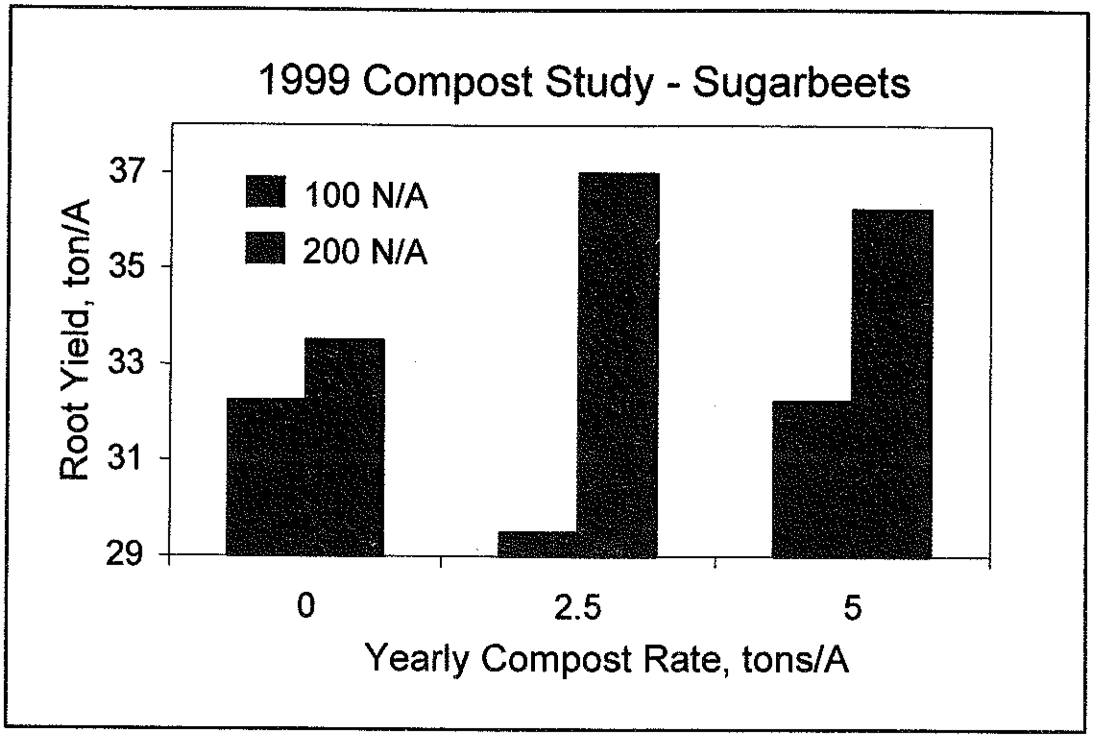
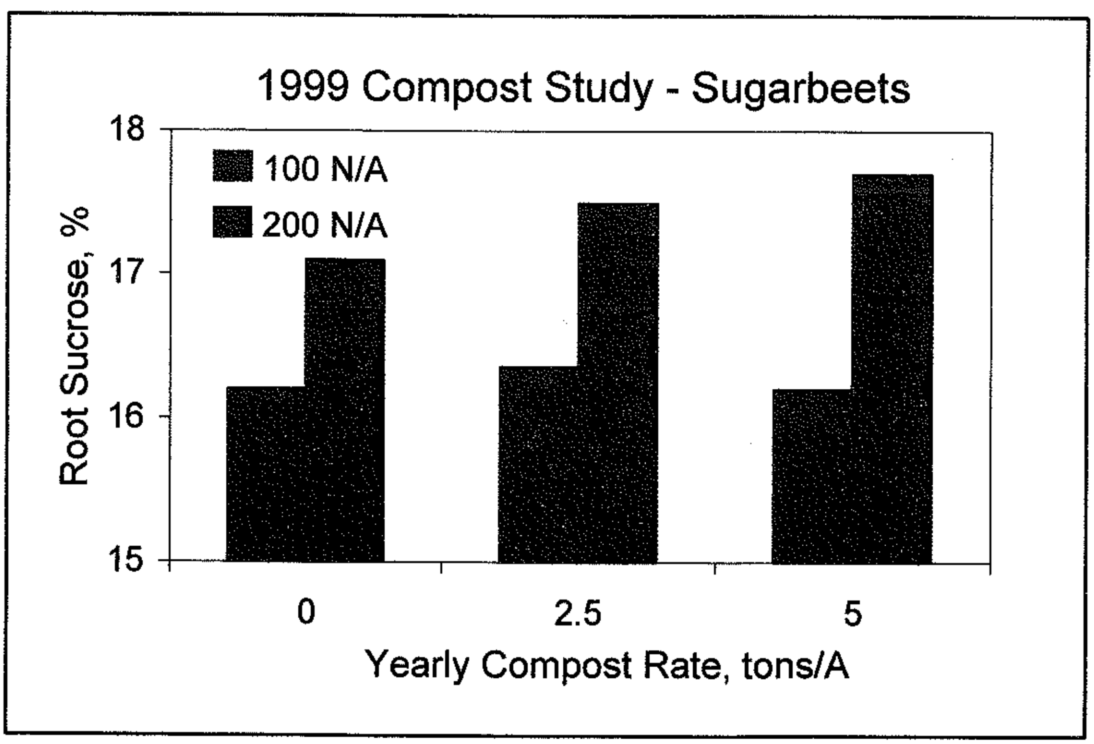
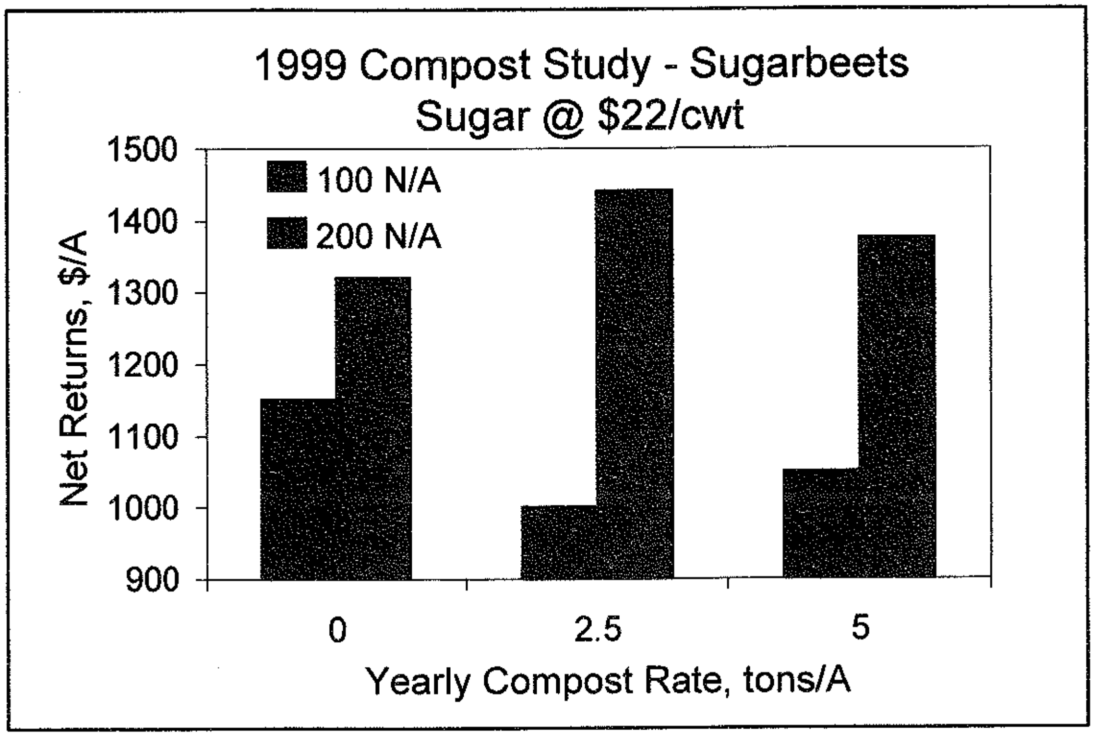
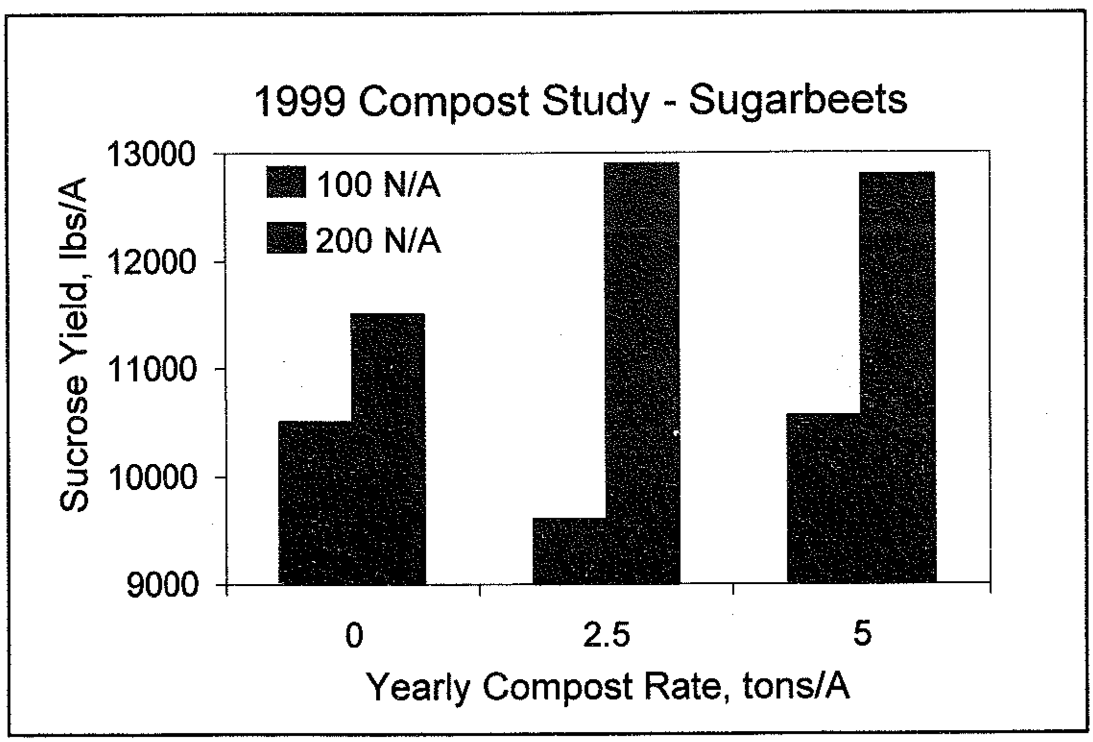

1999 Compost Study - Sugarbeets
100 N/A
200 N/A
Root Yield, ton/A
37
35
33
31
29
0
2.5
5
Yearly Compost Rate, tons/A


1999 Compost Study - Sugarbeets
100 N/A
200 N/A
Root Sucrose, %
18
17
16
15
0
2.5
5
Yearly Compost Rate, tons/A


1999 Compost Study - Sugarbeets
Sugar @ $22/cwt
100 N/A
200 N/A
Net Returns, $/A
1500
1400
1300
1200
1100
1000
900
0
2.5
5
Yearly Compost Rate, tons/A


1999 Compost Study - Sugarbeets
100 N/A
200 N/A
Sucrose Yield, lbs/A
13000
12000
11000
10000
9000
0
2.5
5
Yearly Compost Rate, tons/A