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2000
RESEARCH REPORTS

INDEX

NUTRIENT AVAILABILITY FOR APPLE TREES FROM CHICKEN MANURE AND COMPOST

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Project Summary

The purpose of this study was to evaluate the impact of manure (5 T/acre and 10 T/acre rates) and compost (0.5 and 1.0 T/acre rates) applications to the soil fertility of organic apple orchards. Over a two-year period with annual treatment applications, soil fertility effects generally increased with time in both of the orchards under evaluation. Manure application reduced soil pH and soil calcium levels, while increasing soil salinity and organic matter levels. In addition, manuring increased soil nitrate, ammonium, phosphorus, potassium, zinc, iron (on one of the two farms only), magnesium, and boron. Compost, on the other hand, increased soil salinity (on one farm only) and phosphorus and magnesium levels and rarely impacted soil nitrate and ammonium contents. At this time, it appears that the 5 T/acre manure application rate was the best treatment. The higher manure application rate may increase soil salinity, result in phosphorus runoff, and lead to boron toxicity. The compost application rates were too low to see much positive impact; however, increasing the compost rate could lead to serious soil salinity problems.

Introduction to Topic

Many Hotchkiss area organic apple producers are utilizing chicken manure or composted chicken manure from the Grand Junction and Delta area as an organic fertilizer and soil amendment. The growers requested clarification regarding what the best application rates would be for these two materials and specific information about nutrient availability from them. This research data is meant to provide solid information to the growers so that they have a better foundation for their manure and compost application decisions.

Objectives Statement

The objectives of this study are:

- to determine optimum chicken manure and compost application rates for organic and transitional apple orchards on the West Slope
- to measure the nitrogen release (timing and amount) from manure and compost applications
- to evaluate the impact of manure and compost on plant availability of other nutrients (phosphorus, potassium, calcium, magnesium, zinc, iron, and boron)

Materials and Methods

Two sites were chosen for this research project: a transitional orchard (Steve Ela's) and a certified organic orchard (Kris Kropp's). Both sites are irrigated with micro-sprinklers and are producing Gala apples on trees of about the same age. At each site five treatments were applied on April 14-15, 1999 and again on April 25, 2000: 5 tons/acre Del Mesa 50/50 chicken manure mix with sawdust, 10 tons/acre Del Mesa 50/50 chicken manure mix with sawdust, 0.5 ton/acre Grand Mesa Eggs compost, 1.0 ton/acre Grand Mesa Eggs compost, and a control. There were five replicates at each site laid out in a randomized complete block design (25 plots per site), and each plot was 48 feet wide (three rows) by 24 feet long (nine trees per plot).

Prior to manure or compost application, soil samples were taken on April 14, 1999 for complete analysis (pH, organic matter, electrical conductivity, nitrate, ammonium, phosphorus, potassium, calcium, magnesium, zinc, iron, and boron). At manure/compost application time, manure and compost was sampled for complete analysis. After that, soil samples were taken for nitrate and ammonium analysis every two weeks until after harvest, for a total of 13 sampling times in 1999 and 11 sampling times in 2000. Every three months (April, July, and October of 1999 and 2000), a complete analysis was repeated on the soil samples. Leaf samples were taken in mid-August (August 12-13, 1999) and analyzed for N, S, P, K, Ca, Mg, Na, Zn, Mn, Fe, Cu, Al, and B. Yield was not measured due to the very low yields in 1999, but sugar content and maturity were measured in each plot at harvest time.

Nitrogen (N) is very complicated due to its varying forms and its continual transformation from one form to another. Plants can only take up inorganic N including two different forms, ammonium (NH_4-N) and nitrate (NO_3-N). The organic N in the manure and compost is mineralized to ammonium and then nitrified to nitrate, and both of these processes are microbial. Therefore, these processes are highly dependent on climate and other factors. In addition, nitrate and ammonium are being taken up by plants and nitrate is being leached throughout the growing season, so variability in soil N concentrations is very high.

All data was evaluated as a randomized complete block using the Statistical Analysis Software package. Analysis of variance was followed by the Least Significant Differences Test for mean separation.

Project Results

The manure and the compost had about the same moisture content and N level (Table 1). However, more of the N was in organic forms in the compost than in the manure, as expected. In addition, the compost had a much lower C:N ratio than the manure, which will probably result in quicker release of the organic N for plant uptake. The compost also had a much higher salt content, a higher pH, and higher concentrations of P_2O_5 and K_2O than the manure. The high pH and salt level of the compost could cause problems if applied at rates as high as the manure application rates.

Table 1. Manure and compost characterization.

	Moisture (%)	pH	Soluble Salts (mmhos/cm)	N (lbs/ton)	P_2O_5 (lbs/ton)	K_2O (lbs/ton)	C:N Ratio
Del Mesa manure	19.6	8.3	9.2	32 (84% organic)	52	30	18.8
Grand Mesa Compost	19.3	9.0	56.6	32 (95% organic)	168	48	5.0

Both manure application rates significantly reduced soil pH in both orchards, making it closer to a neutral pH (Table 2). The compost application had no effect on pH, and there was no significant difference in soil pH between the two manure application rates.

The soil electrical conductivity (EC), which is a measure of soluble salt concentration, was significantly increased by both manure application rates and the high compost rates at Ela's (Table 3) and by the high manure application rate at Kropp's (one sampling date only). At Ela's, the high manure application rate (10 T/acre) had a soil EC which was significantly higher than the low manure and high compost application rates.

Both manure application rates significantly increased soil organic matter levels in both orchards (Table 4). Usually, there was no significant difference between manure application rates. In both orchards, soil organic matter levels increased from about 2% to about 4% in the two year study period. This is a remarkable increase in soil organic matter in a short period of time. Compost had no effect on soil organic matter.

All manure and compost treatments significantly increased soil phosphorus (P) levels on both farms (Table 5), but the high manure application rate resulted in the highest soil phosphorus concentration. In fact, the high manure application increased soil test P 10-fold at Ela's and 6-fold at Kropp's. At the time that the study was initiated, Kropp's soil test P levels were about double those of Ela's.

Extractable soil potassium (K) levels were also increased by both manure treatments on both farms (Table 6). The high manure application rate resulted in significantly higher soil K than the low manure application rate; however, both soils (and most western soils) are rich in potassium, and, therefore, did not require additional K.

Table 2. Soil pH as a function of treatment and time on two organic farms.

	April 1999	July 1999	Oct 1999	April 2000	July 2000	Oct 2000
			Ela's			
5 T/ acre manure	7.63	7.43 c	7.33 bc	7.48 b	7.24 cd	7.04 c
10 T/acre manure	7.63	7.50 bc	7.30 c	7.48 b	7.14 d	6.96 c
0.5 T/acre compost	7.60	7.50 bc	7.50 ab	7.62 a	7.40 ab	7.10 bc
1.0 T/acre compost	7.70	7.63 ab	7.47 abc	7.64 a	7.36 bc	7.28 ab
control	7.60	7.67 a	7.63 a	7.72 a	7.52 a	7.32 a
			Kropp's			
5 T/ acre manure	7.73	7.67 bc	7.67	7.64	7.52 bc	7.36 bc
10 T/acre manure	7.70	7.60 c	7.47	7.56	7.42 c	7.30 c
0.5 T/acre compost	7.70	7.60 c	7.67	7.62	7.58 ab	7.46 ab
1.0 T/acre compost	7.73	7.83 a	7.70	7.66	7.62 ab	7.50 a
control	7.73	7.80 ab	7.73	7.68	7.66 a	7.50 a

a, b, c, d Treatments with a common letter on the same farm and sampling date are not significantly different by Least Significant Differences ($p<0.05$).

Table 3. Soil electrical conductivity (mmhos/cm) as a function of treatment and time on two organic farms.

	April 1999	July 1999	Oct 1999	April 2000	July 2000	Oct 2000
			Ela's			
5 T/ acre manure	0.67 b	0.72	0.61	0.72	1.11 b	1.12 b
10 T/acre manure	0.74 b	0.72	0.72	0.73	1.34 a	1.65 a
0.5 T/acre compost	0.72 b	0.58	0.57	0.62	0.74 c	0.97 bc
1.0 T/acre compost	0.61 b	0.68	0.64	0.70	0.95 b	1.05 b
control	0.92 a	0.59	0.51	0.61	0.70 c	0.81 c
			Kropp's			
5 T/ acre manure	0.73	0.69	0.64	0.79	0.81 b	0.86
10 T/acre manure	0.84	0.76	0.77	0.93	1.02 a	1.00
0.5 T/acre compost	0.73	0.67	0.77	0.84	0.75 b	0.76
1.0 T/acre compost	0.61	0.68	0.58	0.83	0.73 b	0.75
Control	0.72	0.58	0.53	0.75	0.67 b	0.77

a, b, c, d Treatments with a common letter on the same farm and sampling date are not significantly different by Least Significant Differences ($p<0.05$).

Table 4.Soil organic matter (%) as a function of treatment and time on two organic farms.

	April 1999	July 1999	Oct 1999	April 2000	July 2000	Oct 2000
			Ela's			
5 T/ acre manure	1.97	2.63	2.23 a	2.44 a	3.34 b	4.38 a
10 T/acre manure	1.97	2.53	2.37 a	2.50 a	4.32 a	4.54 a
0.5 T/acre compost	1.93	2.27	1.70 b	2.04 b	2.92 bc	3.42 b
1.0 T/acre compost	2.23	2.50	1.83 b	2.10 b	2.94 bc	3.10 b
control	2.03	2.20	1.63 b	2.04 b	2.46 c	3.08 b
			Kropp's			
5 T/ acre manure	2.13	3.10 a	2.77	2.48 b	3.62 a	3.92 a
10 T/acre manure	2.03	3.33 a	3.93	2.78 a	4.16 a	4.60 a
0.5 T/acre compost	1.87	2.27 b	2.43	2.32 bc	2.76 b	2.84 b
1.0 T/acre compost	1.90	2.23 b	2.60	2.44 bc	2.82 b	2.90 b
control	1.97	2.23 b	2.63	2.24 c	2.72 b	2.84 b

a, b, c, d Treatments with a common letter on the same farm and sampling date are not significantly different by Least Significant Differences (p<0.05).

Table 5. Soil phosphorus (ppm Olsen P) as a function of treatment and time on two organic farms.

	April 1999	July 1999	Oct 1999	April 2000	July 2000	Oct 2000
			Ela's			
5 T/ acre manure	26	64	61 b	67 b	166 bc	246 b
10 T/acre manure	30	81	100 a	98 a	294 a	355 a
0.5 T/acre compost	49	64	53 b	51 bc	120 c	167 c
1.0 T/acre compost	54	103	59 b	35 c	218 b	189 c
control	53	49	30 c	38 c	56 d	59 d
			Kropp's			
5 T/ acre manure	100	152 ab	149 ab	161 b	349 a	403 b
10 T/acre manure	92	166 a	173 a	251 a	400 a	553 a
0.5 T/acre compost	93	151 ab	136 b	142 b	257 b	380 b
1.0 T/acre compost	94	144 b	141 b	161 b	343 a	453 ab
control	96	113 c	126 b	117 b	190 c	212 c

a, b, c, d Treatments with a common letter on the same farm and sampling date are not significantly different by Least Significant Differences (p<0.05).

Table 6. Soil potassium (ppm) as a function of treatment and time on two organic farms.

	April 1999	July 1999	Oct 1999	April 2000	July 2000	Oct 2000
			Ela's			
5 T/ acre manure	467	723 b	466 b	620	1032 b	1167 b
10 T/acre manure	458	805 ab	627 a	691	1435 a	1630 a
0.5 T/acre compost	595	761 b	557 a	523	688 c	981 bc
1.0 T/acre compost	569	948 a	577 a	541	1023 b	1006 bc
control	537	657 b	432 b	544	608 c	679 c
			Kropp's			
5 T/ acre manure	745	1008	909	793 bc	985 b	1008 b
10 T/acre manure	776	1123	973	940 a	1388 a	1318 a
0.5 T/acre compost	816	991	853	779 bc	843 bc	910 bc
1.0 T/acre compost	784	916	851	818 b	867 bc	955 bc
control	809	822	800	715 c	679 c	769 c

a, b, c, d Treatments with a common letter on the same farm and sampling date are not significantly different by Least Significant Differences ($p<0.05$).

The compost treatments had mixed results at Ela's and no significant impact at Kropp's.

Manure application also increased soil zinc (Zn) levels in both orchards (Table 7). In general, compost applications had no significant impact on soil Zn. And, in general, the 10 T/acre manure application rate did not result in significantly different soil Zn levels than the 5 T/ acre rate.

There was no significant impact of manure or compost treatments on soil iron (Fe) levels at Ela's (Table 8). However, there was a significant difference at Kropp's in July and October 2000. Manure increased soil iron at Kropp's, but compost had no effect. The two manure application rates were not significantly different.

Interestingly, manure application significantly reduced soil calcium (Ca) levels at Ela's in July and October of 2000 and at Kropp's in July 2000 (Table 9). Compost treatments and mixed results at Ela's and no impact at Kropp's. In general, there was no significant difference between manure application rates.

All manure and compost treatments increased soil magnesium (Mg) levels at at least one sampling date towards the end of the second year of the study on both farms (Table 10). However, manure increased soil Mg more than compost did.

Manure application significant increased soil B levels in both orchards (Table 11). Compost treatments had mixed results at Ela's and no effect at Kropp's. Usually, there was no significant difference between manure application rates.

At Ela's in 1999, there were significant differences in soil inorganic N forms on only a few sampling dates. On June 10 and June 24, the manured treatments had significantly higher nitrate levels than the control (Table 12). On the final sampling date of the 1999 season (October 8), both the high manure and the high compost treatments had soil nitrate levels which were significantly higher than the control. The high manure application rate also resulted in significantly higher soil ammonium levels on April 28 and October 8, 1999 (Table 13). The only difference in ammonium between compost treatments and the control occurred on September 12, 1999, and the compost treatments had lower soil ammonium levels than the control.

At Kropp's Orchard in 1999, there were some consistent results across time. The high manure application rate significantly increased soil nitrate levels, as compared to the control, on April 28, May 27, June 11, June 24, and July 22 (Table 14). The high manure rate also significantly increased soil ammonium levels on May 27, June 11, September 12, and September 24 (Table 15). Even the low manure application rate increased soil nitrate on April 28 and soil ammonium on September 12. The compost treatments had no significant impact on soil nitrate or ammonium levels at Kropp's in 1999.

Table 7. Soil zinc (ppm) as a function of treatment and time on two organic farms.

	April 1999	July 1999	Oct 1999	April 2000	July 2000	Oct 2000
			Ela's			
5 T/ acre manure	7.8	13.5	15.3	8.6 a	14.6 abc	27.7 a
10 T/acre manure	10.2	13.3	15.2	8.2 ab	17.9 a	26.2 a
0.5 T/acre compost	8.9	12.0	12.6	6.6 abc	16.4 ab	21.1 ab
1.0 T/acre compost	7.8	12.6	11.5	5.3 bc	12.4 bc	14.1 b
control	9.4	12.0	12.2	4.7 c	10.8 c	15.6 b
			Kropp's			
5 T/ acre manure	4.5	8.9 ab	8.5	4.3 c	10.4 a	13.8 ab
10 T/acre manure	3.9	10.4 a	10.4	5.9 a	12.4 a	18.1 a
0.5 T/acre compost	3.9	8.7 b	7.3	4.3 c	7.2 b	9.2 b
1.0 T/acre compost	4.5	8.2 b	7.5	5.1 b	8.2 b	9.9 b
control	4.0	7.3 b	7.6	3.8 c	7.0 b	9.3 b

a, b, c, d Treatments with a common letter on the same farm and sampling date are not significantly different by Least Significant Differences ($p<0.05$).

Table 8. Soil iron (ppm) as a function of treatment and time on two organic farms.

	April 1999	July 1999	Oct 1999	April 2000	July 2000	Oct 2000
			Ela's			
5 T/ acre manure	12.3	17.7	25.7	12.8	14.9	27.0
10 T/acre manure	12.0	16.7	19.7	12.3	14.9	21.6
0.5 T/acre compost	12.4	18.6	20.5	12.0	13.8	24.6
1.0 T/acre compost	13.5	15.9	19.8	11.2	11.5	16.4
control	12.0	18.8	18.7	11.8	12.4	21.5
			Kropp's			
5 T/ acre manure	10.3	19.0	22.5	11.3	18.6 ab	26.0 ab
10 T/acre manure	13.0	18.7	19.9	11.7	19.8 a	27.5 a
0.5 T/acre compost	12.5	21.6	21.1	11.8	14.6 c	19.0 c
1.0 T/acre compost	13.7	20.3	20.8	12.3	15.7 bc	20.4 c
control	12.3	18.5	21.6	11.2	14.7 c	21.5 bc

a, b, c, d Treatments with a common letter on the same farm and sampling date are not significantly different by Least Significant Differences ($p<0.05$).

Table 9. Soil calcium (ppm) as a function of treatment and time on two organic farms.

	April 1999	July 1999	Oct 1999	April 2000	July 2000	Oct 2000
			Ela's			
5 T/ acre manure	4751 b	4742	4827	5456 c	4550 bc	4513 b
10 T/acre manure	5093 a	4931	4759	5529 bc	4216 c	4526 b
0.5 T/acre compost	4809 b	4664	4934	6163 a	4808 b	5056 a
1.0 T/acre compost	5125 a	4774	5001	5792 abc	4659 b	5237 a
control	5171 a	4874	5080	5906 ab	5470 a	5158 a
			Kropp's			
5 T/ acre manure	4952	4922	5092	5603	5440 a	5208
10 T/acre manure	5421	4963	5497	5574	4987 b	4991
0.5 T/acre compost	5049	5217	5314	5491	5759 a	5368
1.0 T/acre compost	5070	5372	5308	5752	5555 a	5449
control	4980	5342	5398	5647	5648 a	5524

a, b, c, d Treatments with a common letter on the same farm and sampling date are not significantly different by Least Significant Differences ($p<0.05$).

Table 10. Soil magnesium (ppm) as a function of treatment and time on two organic farms.

	April 1999	July 1999	Oct 1999	April 2000	July 2000	Oct 2000
			Ela's			
5 T/ acre manure	445	478	487	587 abc	551	694 ab
10 T/acre manure	422	466	455	597 ab	616	754 a
0.5 T/acre compost	455	467	473	639 a	547	654 bc
1.0 T/acre compost	428	439	437	559 bc	535	617 c
Control	418	459	427	522 c	505	535 d
			Kropp's			
5 T/ acre manure	436	486 b	512 b	568	595 ab	619 b
10 T/acre manure	477	535 a	582 a	599	629 a	715 a
0.5 T/acre compost	472	466 b	467 b	521	550 b	564 bc
1.0 T/acre compost	458	475 b	484 b	566	560 b	603 b
Control	465	454 b	460 b	532	493 c	516 c

a, b, c, d Treatments with a common letter on the same farm and sampling date are not significantly different by Least Significant Differences ($p<0.05$).

Table 11. Soil boron (ppm) as a function of treatment and time on two organic farms.

	April 1999	July 1999	Oct 1999	April 2000	July 2000	Oct 2000
			Ela's			
5 T/ acre manure	0.98	1.31	1.28	0.88 a	1.53 bc	1.97 ab
10 T/acre manure	0.99	1.43	1.68	0.86 ab	2.18 a	2.30 a
0.5 T/acre compost	0.99	1.51	1.15	0.73 bc	1.19 cd	1.66 bc
1.0 T/acre compost	1.02	1.54	1.11	0.70 c	1.62 b	1.42 cd
control	0.78	1.01	0.94	0.68 c	0.96 d	1.04 d
			Kropp's			
5 T/ acre manure	0.72	1.14 b	1.03	0.54 b	0.83 a	0.88 ab
10 T/acre manure	0.66	1.50 a	1.63	0.72 a	1.03 a	1.20 a
0.5 T/acre compost	0.62	0.94 bc	0.86	0.57 b	0.57 b	0.64 b
1.0 T/acre compost	0.65	0.88 c	0.89	0.57 b	0.59 b	0.65 b
control	0.74	0.79 c	0.83	0.52 b	0.52 b	0.55 b

a, b, c, d Treatments with a common letter on the same farm and sampling date are not significantly different by Least Significant Differences ($p<0.05$).

Table 12. Soil nitrate (ppm NO_3-N) as a function of treatment and time on Ela's Orchard in 1999.

Sampling Date			Treatment		
	5 T/ acre manure	10 T/acre manure	0.5 T/acre compost	1.0 T/acre compost	control
April 14	36.1	42.2	44.0	29.4	66.5
April 28	48.9	45.5	40.7	52.6	34.3
May 13	44.2	61.1	33.3	34.1	19.8
May 27	34.0	42.1	19.2	42.0	29.6
June 10	28.5 a	33.0 a	12.6 b	21.9 ab	11.7 b
June 24	21.1 a	16.1 a	8.6 c	15.9 ab	10.0 bc
July 8	23.8	35.4	17.0	17.1	26.2
July 22	15.9	18.8	11.6	21.4	8.9
August 5	28.2	45.0	10.0	14.3	20.6
August 20	29.8	29.9	10.7	38.6	16.0
Sept. 12	29.2	44.5	13.3	28.0	36.6
Sept. 24	65.8 a	24.6 c	33.4 bc	56.3 ab	41.5 abc
October 8	23.5 ab	31.1 a	11.9 b	31.9 a	12.1 b

a, b, c, d Treatments with a common letter on the same sampling date are not significantly different by Least Significant Differences ($p<0.05$).

Table 13. Soil ammonium (ppm NH_4-N) as a function of treatment and time on Ela's Orchard in 1999.

Sampling Date			Treatment		
	5 T/ acre manure	10 T/acre manure	0.5 T/acre compost	1.0 T/acre compost	control
April 14	15.1	15.7	15.5	11.1	22.9
April 28	11.9 b	25.1 a	9.4 b	12.2 b	7.1 b
May 13	24.5	10.3	10.2	15.1	6.2
May 27	8.2	9.3	9.6	9.8	10.0
June 10	8.4	7.3	5.8	5.3	5.6
June 24	5.8	6.0	4.8	5.4	5.9
July 8	6.1	7.8	5.0	3.2	4.7
July 22	8.5	8.0	7.9	6.8	6.7
August 5	11.3	11.8	9.0	10.3	7.8
August 20	29.6	11.9	6.6	7.6	5.8
Sept. 12	5.0 bc	6.8 a	4.3 c	4.0 c	5.7 ab
Sept. 24	6.7	6.4	6.2	5.1	6.3
October 8	4.7 ab	5.0 a	3.8 ab	3.6 b	3.4 b

a, b, c, d Treatments with a common letter on the same sampling date are not significantly different by Least Significant Differences ($p<0.05$).

Table 14. Soil nitrate (ppm NO_3-N) as a function of treatment and time on Kropp's Orchard in 1999.

Sampling Date			Treatment		
	5 T/ acre manure	10 T/acre manure	0.5 T/acre compost	1.0 T/acre compost	control
April 14	21.6	20.5	11.5	12.8	13.4
April 28	34.4 b	53.8 a	11.2 c	14.0 c	6.7 c
May 27	27.4 b	48.3 a	13.8 b	17.1 b	11.1 b
June 11	23.3 ab	33.1 a	20.1 ab	20.5 ab	9.2 b
June 24	20.1 ab	30.5 a	11.1 b	18.9 ab	9.5 b
July 8	12.4	19.8	10.6	17.1	21.5
July 22	11.2 b	26.4 a	8.8 b	14.8 ab	8.5 b
August 5	15.3	15.6	8.4	14.9	10.6
August 20	52.4	21.8	90.8	75.2	56.0
Sept. 12	13.2	16.8	10.6	11.1	8.7
Sept. 24	7.6	12.2	6.5	5.4	11.1
October 8	13.3	26.8	39.4	12.0	10.6

a, b, c, d Treatments with a common letter on the same sampling date are not significantly different by Least Significant Differences ($p<0.05$).

Table 15. Soil ammonium (ppm NH_4-N) as a function of treatment and time on Kropp's Orchard in 1999.

Sampling Date			Treatment		
	5 T/ acre manure	10 T/acre manure	0.5 T/acre compost	1.0 T/acre compost	control
April 14	10.2	10.2	9.1	9.2	11.1
April 28	9.4 ab	12.4 a	6.5 b	7.4 b	9.1 ab
May 27	8.9 ab	10.0 a	6.9 b	6.7 b	7.0 b
June 11	8.9 b	14.5 a	7.6 b	7.6 b	6.6 b
June 24	7.5	17.7	5.8	7.1	5.8
July 8	7.9	5.8	4.2	4.6	3.5
July 22	5.5	6.6	6.6	5.1	4.8
August 5	9.8	9.1	6.9	7.9	7.1
August 20	12.2	7.2	7.6	9.9	8.7
Sept. 12	9.7 a	8.0 ab	5.1 bc	6.5 abc	4.5 c
Sept. 24	4.0 b	6.4 a	3.6 b	4.1 b	3.5 b
October 8	4.5	6.2	4.4	4.2	4.4

a, b, c, d Treatments with a common letter on the same sampling date are not significantly different by Least Significant Differences ($p<0.05$).

In 2000, more differences became apparent at Ela's Orchard. The high manure application rate had soil nitrate levels that were significantly higher than the control on May 11, May 24, July 6, July 21, August 1, September 1, and October 1 (Table 16). The low manure application rate also had soil nitrate levels significantly greater than the control on July 6, July 21, August 1, and October 1. On the other hand, the compost treatments were not significantly different from the control in soil nitrate on any date in 2000.

The high manure application rate also resulted in significantly higher soil ammonium at Ela's on April 25, May 11, June 23, July 6, July 21, and August 1 of 2000 (Table 17). The low manure application rate had significantly higher soil ammonium levels than the control on April 25, May 11, and July 21. The low compost rate had soil ammonium levels which were significantly higher than the control on July 21, September 1, and October 1.

At Kropp's in 2000, the high manure application rate significantly increased soil nitrate on April 25, May 11, May 24, June 23, July 21, August 1, September 1, and October 1 (Table 18), and soil ammonium on April 25, May 11, May 24, June 9, and July 21 (Table 19). The low manure application rate also increased soil nitrate on April 25, May 11, August 1, and October 1, and soil ammonium on April 25, May 11, May 24. The compost treatments had very little effect on inorganic soil N at Kropp's. The only significant impact occurred on April 25 and June 23, when the high compost rate had significantly higher soil nitrate than the control.

Leaf samples showed no significant treatment differences at either location in 1999 for any of the nutrients measured (N, S, P, K, Ca, Mg, Na, Zn, Mn, Fe, Cu, Al, and B). The impact of the treatments in the first year was not enough to affect the nutritional status of the trees. It may take a few years' time to develop differences in the trees' nutritional status. None of the plots were deficient in nitrogen. There were also no significant differences among treatments in sugar content or maturity of the apples themselves.

Table 16. Soil nitrate (ppm NO_3-N) as a function of treatment and time on Ela's Orchard in 2000.

Sampling Date			Treatment		
	5 T/ acre manure	10 T/acre manure	0.5 T/acre compost	1.0 T/acre compost	control
April 25	59.0	64.2	27.0	59.8	39.0
May 11	116.5 b	363.8 a	31.2 b	65.2 b	44.4 b
May 24	45.2 ab	87.8 a	20.0 b	27.4 b	21.8 b
June 9	58.2	57.4	32.2	60.2	70.6
June 23	87.2	43.2	40.4	80.8	37.4
July 6	107.2 ab	145.0 a	23.4 d	76.8 bc	39.6 cd
July 21	73.0 a	63.0 ab	15.6 c	31.2 bc	19.8 c
August 1	44.8 ab	57.4 a	7.6 c	22.2 bc	10.2 c
August 21	109.2	175.4	36.8	70.2	65.8
Sept. 1	95.8 b	245.4 a	37.0 b	50.0 b	36.0 b
October 1	366.5 ab	400.2 a	97.5 c	177.5 bc	86.4 c

a, b, c, d Treatments with a common letter on the same sampling date are not significantly different by Least Significant Differences ($p<0.05$).

Table 17. Soil ammonium (ppm NH_4-N) as a function of treatment and time on Ela's Orchard in 2000.

Sampling Date			Treatment		
	5 T/ acre manure	10 T/acre manure	0.5 T/acre compost	1.0 T/acre compost	control
April 25	21.0 a	16.2 b	11.2 c	10.8 c	10.0 c
May 11	25.6 b	40.6 a	14.8 c	23.6 bc	14.6 c
May 24	14.6	18.2	9.8	21.6	11.8
June 9	33.2	42.4	27.8	42.2	28.6
June 23	29.0 b	43.2 a	18.4 c	25.8 bc	22.6 bc
July 6	28.2 b	66.8 a	25.4 b	22.4 b	29.6 b
July 21	18.0 ab	20.8 a	17.6 ab	11.0 bc	9.6 c
August 1	3.40 ab	4.60 a	1.8 b	1.8 b	2.0 b
August 21	16.4	20.2	17.0	11.6	13.8
Sept. 1	18.0 b	20.0 b	31.8 a	22.0 b	18.4 b
October 1	26.2 b	46.0 b	89.8 a	28.5 b	29.0 b

a, b, c, d Treatments with a common letter on the same sampling date are not significantly different by Least Significant Differences ($p<0.05$).

Table 18. Soil nitrate (ppm NO_3-N) as a function of treatment and time on Kropp's Orchard in 2000.

Sampling Date			Treatment		
	5 T/ acre manure	10 T/acre manure	0.5 T/acre compost	1.0 T/acre compost	control
April 25	55.6 b	92.0 a	42.4 bc	57.8 b	32.8 c
May 11	243.5 b	426.0 a	59.2 c	79.0 c	38.4 c
May 24	74.0 b	229.8 a	37.8 b	36.2 b	18.8 b
June 9	95.0	73.0	86.8	55.6	36.8
June 23	53.0 c	105.2 a	64.6 bc	82.4 ab	43.8 c
July 6	78.2	95.0	52.8	66.0	39.8
July 21	36.8 b	95.8 a	23.4 b	26.6 b	21.0 b
August 1	33.0 a	39.0 a	12.2 b	15.4 b	10.4 b
August 21	66.8	78.8	73.2	61.2	43.2
Sept. 1	73.4 b	18.8 a	51.0 b	49.6 b	44.4 b
October 1	172.4 a	115.2 b	46.0 c	60.4 c	64.4 c

a, b, c, d Treatments with a common letter on the same sampling date are not significantly different by Least Significant Differences ($p<0.05$).

Soil ammonium (ppm NH_4-N) as a function of treatment and time on Kropp's Orchard in 2000.

Sampling Date			Treatment		
	5 T/ acre manure	10 T/acre manure	0.5 T/acre compost	1.0 T/acre compost	control
April 25	15.2 a	15.8 a	12.2 ab	9.4 b	8.8 b
May 11	50.2 a	52.2 a	24.2 b	28.2 b	16.4 b
May 24	24.0 b	33.6 a	17.2 bc	19.8 bc	14.2 c
June 9	43.8 b	67.2 a	37.6 b	30.6 b	33.4 b
June 23	30.4	44.0	29.0	32.2	26.2
July 6	30.0	31.8	20.8	26.8	21.8
July 21	20.8 ab	27.0 a	18.0 b	16.6 b	13.8 b
August 1	3.6	3.6	2.2	2.6	3.8
August 21	17.6	21.0	20.2	18.4	18.2
Sept. 1	18.0	20.6	24.8	20.2	18.4
October 1	35.8	38.8	36.8	23.4	29.8

a, b, c, d Treatments with a common letter on the same sampling date are not significantly different by Least Significant Differences ($p<0.05$).

Conclusions and Discussion

- Manure application reduced soil pH.
- Manure application and the high compost rate increased soil EC.

Apples are moderately tolerant of soil salinity; they are less tolerant than grapes, but more tolerant than pears and peaches (Soltanpour and Follett, 1995). When the soil EC gets above 1.7 mmhos/cm, apple yields have been shown to decline. A 10% yield decline can be expected when soil EC reaches 2.3, and a 25% yield decline is expected at 3.3 mmhos/cm. At Ela's, the high manure application rate reached 1.65 mmhos/cm in October 2000. This salinity level is dangerously close to causing a yield reduction for apples.

- Manure application increased soil organic matter.
- Manure and compost application increased soil P.

Although high soil test P is desirable for plant production, there are potential negative environmental impacts from excessive soil test P. Numerous studies have shown that runoff P levels are correlated to soil test P levels; therefore, the greater the soil test P, the greater the potential for P to leave the site in runoff and end up degrading surface water quality. Therefore, it is important, that we apply adequate P to meet crop needs without exceeding them. In Colorado, it is illegal to apply biosolids and hog manure to soils with P concentrations above 100 ppm. In our study, all manure and compost treatments have soil test P levels above 100 ppm after two years of applications.

In addition to the surface water hazard, excess P can also reduce zinc and calcium uptake by fruit trees, by binding them in forms that are not available to plant roots. According to Table 20, soil P levels were adequate in both orchards prior to study initiation.

- Manure application increased soil K.

According to Colorado State University's fertilizer suggestions, soils with K levels above 120 ppm have adequate K for most crops. These soils had levels well above that before the study began.

Table 20. Optimum soil nutrient levels for tree crop production (from Tree Fruits Nutrition).

Nutrient	Soil Sufficiency Level (ppm)
Phosphorus (P)	20-25
Potassium (K)	100
Zinc (Zn)	5-8
Iron (Fe)	50
Calcium (Ca)	500
Magnesium (Mg)	200
Boron (B)	0.8-1.2 (toxic above 2)

- Manure application increased soil Zn on both farms and soil Fe on Kropp's.

Iron and zinc are two nutrients which are often deficient in high pH soils, like those at Ela's and Kropp's. Manure increased plant available soil Zn levels on both farms and soil Fe levels at Kropp's. The reason for this could be two-fold: the Zn and Fe in the manure, and the ability of the additional organic material to chelate Zn and Fe and make them more available to plant roots. Kropp's soil started out in 1999 with soil Zn levels below optimum, but all treatments were above optimum by July 2000. Both orchards have Fe levels which are below optimum even after two years of manure or compost application. This is not surprising due to the high pH and calcareous nature of these soils.

- Manure and compost application increased soil Mg, and manure application decreased soil Ca.

Potassium, calcium, and magnesium are all cations (positively charged ions), and they compete for cation exchange sites on soil clays and for entry into plant roots. Therefore, an excess of one of these nutrients can reduce the soil test levels or plant uptake of the other nutrients. The reduction in soil Ca, noted in Table 9, may be due to the high K application in the manured treatments (150 lbs K_2O/acre/year and 300 lbs K_2O/acre/year for the 5 T/acre and 10 T/acre treatments, respectively), and may also be a reflection of the reduced soil pH (noted in Table 2). However, Ca and Mg levels remain more than adequate for good apple tree nutrition.

- Manure application increased soil B.

The range for boron sufficiency in soil's is quite narrow, from 0.8-1.2 ppm. Kropp's soil started the study with less than optimum B levels, and now at the end of 2000 is still deficient in B except for the manured treatments. Unfortunately, when soil B increases to 2 ppm or higher, a toxic effect can be seen in tree fruit crops. The high manure application resulted in soil B levels above 2 ppm at Ela's in both July and October 2000. The low manure application rate almost reached 2 ppm in October 2000, as well. It may be that the higher organic matter levels protect from B toxicity in this situation, but this was not evaluated.

- Manure application increased soil NO_3-N and NH_4-N levels consistently, but compost increased soil NO_3-N and NH_4-N levels rarely.

Impact of manure increased with time during this study. Manure consistently increased soil NO_3-N and NH_4-N levels on both farms, while the compost treatments rarely had any significant effect on soil inorganic N levels. Too much N can retard fruit development and maturity and diminish fruit quality, so it is important that excessive manure is not applied in order to avoid excessive N uptake by the apple trees.

These two years of data on two organic orchards leads to the conclusion that the 5 T/acre manure application rate does a good job of improving the soil fertility of these orchards. The higher manure application rate occasionally resulted in greater fertility than the low rate, but at the cost of increasing soil salinity, potential for phosphorus runoff, development of possible boron toxicity, and potential cation imbalances.

The compost application rates rarely had any significant impact on soil fertility. Higher compost application rates are needed to gain any soil fertility benefit. However, care should be taken to avoid the development of soil salinity or excessive soil P levels.

Outreach

We will present this information at the 2001 Organic Tree Fruit Conference and at the 2001 American Society of Agronomy annual national meeting. Other possible presentations include next year's Colorado Organic Producers Association conference and the Colorado State University Soil and Crop Sciences Department seminar. We will publish a journal article after the third year of data is collected.

References

Soltanpour, P.N., and R.H. Follett. 1995. Crop tolerance to soil salinity. Colorado State University Cooperative Extension factsheet no 0.505.

Tree Fruits Nutrition, chapter III, pp. 186-213.

PROJECT TITLE: Organic Soil Amendment Release Rates For Fertility in Apples

SUBMITTED BY: Jennifer L. Doles and Rick J. Zimmerman

PROJECT SUMMARY:

This project was initiated by apple producer Steve Ela and Dr. Jessica Davis (CSU) in 1999 to investigate how organic soil amendments impact apple production. Specifically, the project was designed to determine when nutrients become available from applied manures and how long they remain available for plant uptake. Such knowledge allows farmers to manage their manure applications to optimally impact tree vigor and fruit quality. Furthermore, such knowledge can make it possible to minimize losses via leaching and volatilization. In order to carry out the objectives set forth, two research sites were established: a transitional orchard and a certified organic orchard. In 1999 and 2000, soil samples were taken from the treatment plots at regular four-week intervals beginning in May and concluding in October. All of the nutrient analysis was performed by Dr. Jessica Davis at Colorado State University (results from this part of the study will be discussed in a separate report). In 2000, additional soil samples were collected at regular four-week intervals beginning in June and concluding in September to analyze microbial biomass in response to different manure/compost application rates. All soil samples for microbial analysis were processed at the Rogers Mesa Research Center. For bacteria, there was no significant treatment effect ($p = 0.1658$). There was, however, a significant site effect ($p = 0.0049$), with the total number of colony forming units (CFU's) being significantly higher at the Kropp site in comparison to the Ela site. Additionally, there was a significant date effect ($p = 0.0009$); for both sites, CFU's were higher in June and September in comparison to July and August. There was no significant treatment effect ($p = 0.3845$) for total meters of fungal hyphae in either site. Furthermore, there was no significant site and/or date effect. The obtained results suggest: 1.) increased manure/compost application rates do not necessarily result in increased microbial biomass; 2) there is a large amount of temporal variability in microbial biomass; 3.) microbial biomass may be suppressed in transitional orchards in comparison to certified organic orchards.

INTRODUCTION / RESEARCH OBJECTIVES:

In perennial agroecosystems, *i.e.* apple orchards, deciduous trees supply bacteria and fungi with energy inputs (organic matter) on an annual basis. However, the input of organic matter with a high C:N ratio frequently results in microbial immobilization of nitrogen (N) and other nutrients. In order to compensate for this, fertilizers are applied to ensure there is an adequate supply of N for both microbes and plants, shifting the system from net immobilization to mineralization. Hence, it is of critical importance to understand how different manure/compost application rates affect microbial biomass. An understanding of the belowground response (*i.e.* microbes) to manure/compost application rates can allow for predictions to be made about the aboveground response (*i.e.* fruit production and quality). The objective of this research was to quantify the response of bacteria and fungi to different manure/compost application rates. This information would then be used to contribute to the large question of determining how manure/compost application rates influence fruit production and quality.

METHODS:

The study took place in a transitional organic Gala orchard (Steve Ela) and a certified organic Gala orchard (Kris Kropp). At both sites there were five treatments, replicated five times. The treatments were as follows:

1.) 5 tons/acre Del Mesa 50/50 chicken manure mix with sawdust
2.) 10 tons/acre Del Mesa 50/50 chicken manure mix with sawdust
3.) 1 ton/acre Grand Mesa Eggs chicken manure compost
4.) 2 ton/acre Grand Mesa Eggs chicken manure compost
5.) Control – no manure/compost

Treatments were compared to test for differences in microbial response to different manure/compost application rates. Sites were compared to test for differences in microbial biomass as a result of transition from a conventional system as compared to a system that has been treated organically for a number of years. Soil samples were taken on June 15, July 11, August 2, and September 3, 2000. A 5 x 10 cm soil corer was used to obtain fifty samples, each consisting of three sub-samples, from the Kropp and Ela sites per sample date. The samples were homogenized and used to determine soil moisture (%) and to enumerate fungi and bacteria. To determine soil moisture, approximately 10 grams of soil was weighed, dried in a heating oven for 48 hours and re-weighed immediately after removal from the drying oven. Percent moisture was calculated as: ((wet soil - dry soil)/ dry soil) * 100. Bacteria were enumerated using a standard plate count method and plate count numbers were converted to the number of colony forming units per gram of dry soil. Fungi were enumerated by direct fungal counts and meters of hyphae calculated according to Lodge and Ingham (1991). Analysis of variance (ANOVA) was used to test for treatment, site, and date differences; treatment*site and date*treatment interactions were also tested. All significant differences are reported at the $p \leq 0.05$ level.

RESULTS

Fungal – Meters of hyphae

There was no significant treatment effect (p = 0.3845) (Table 1). Furthermore, there was no significant site or date effect.

Bacteria – Colony Forming Units

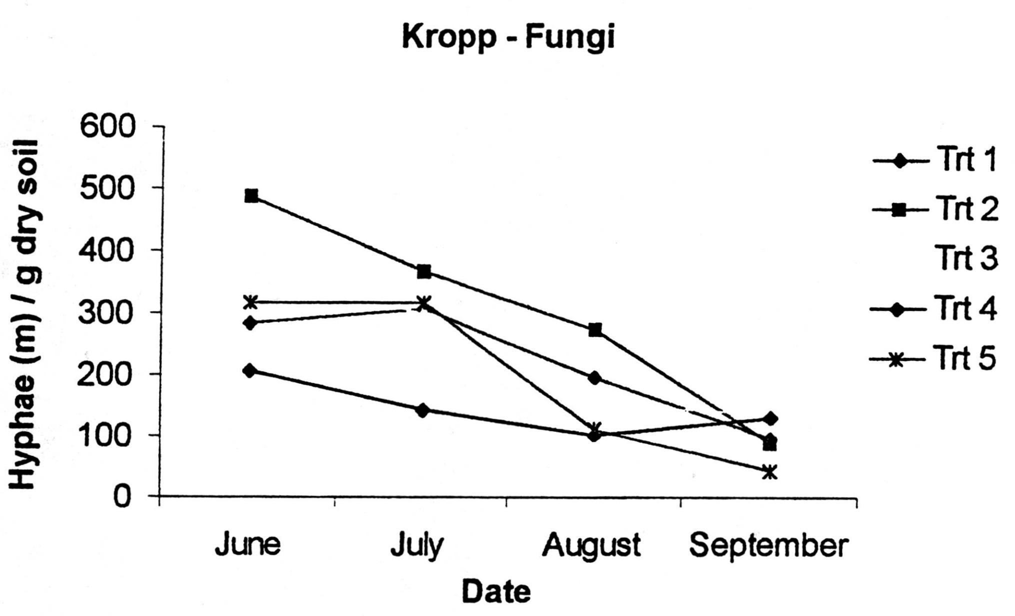
There was no significant treatment effect (p = 0.1658). There was, however, a significant site effect (p = 0.0049), with CFU's being significantly higher at the Kropp site in comparison to the Ela site (Table 2). Additionally, there also was a significant date effect (p = 0.0009); CFU's were higher in June and September in comparison to July and August.

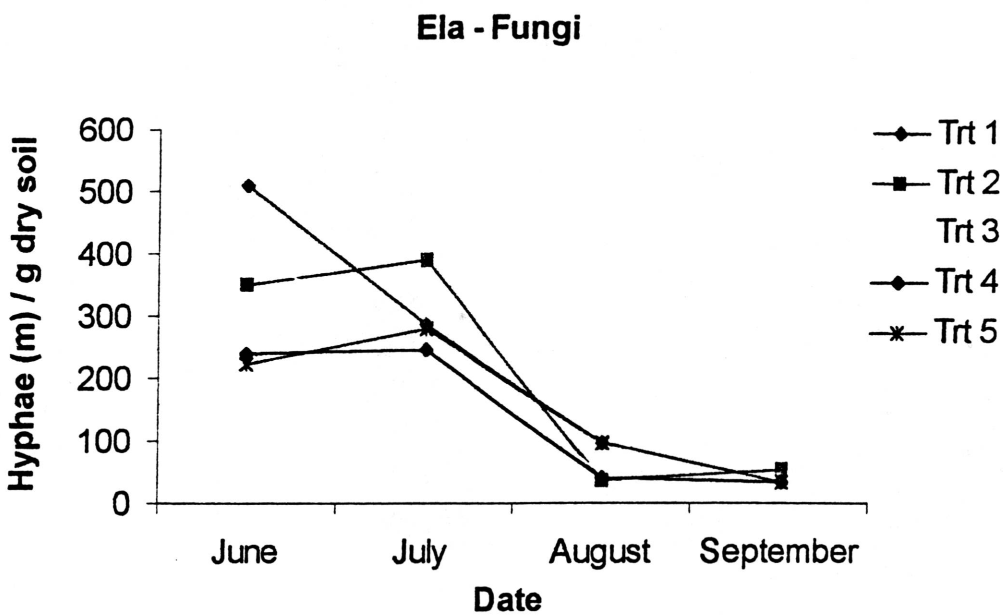
Table 1.0 Meters of hyphae per gram of dry soil. Numbers represent average of five samples for each treatment.

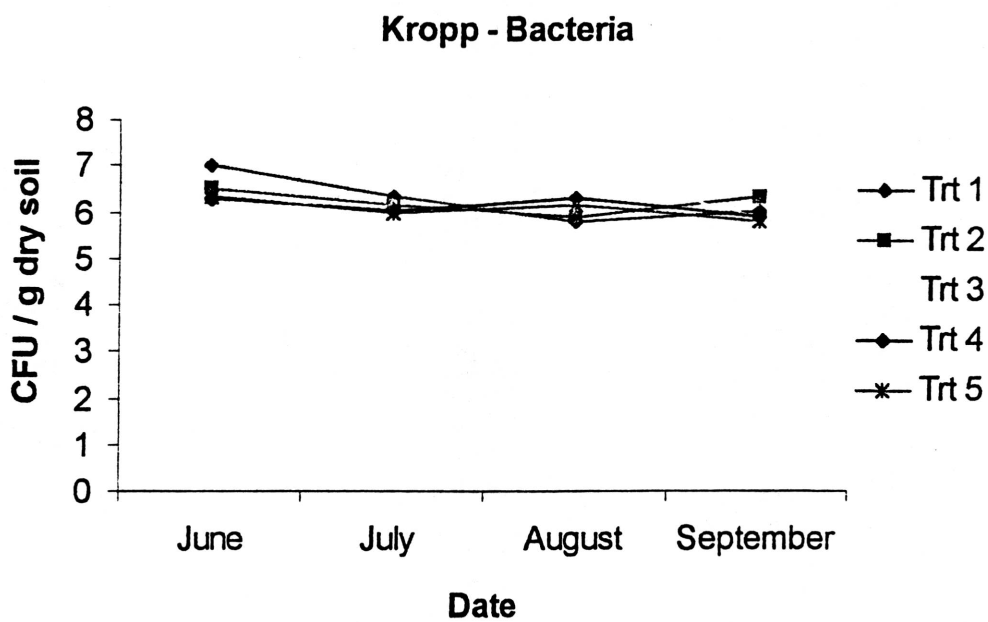
		Site 1					Site 2		
		Ela					Kropp		
Treatment	Date 1	Date 2	Date 3	Date 4		Date 1	Date 2	Date 3	Date 4
1	508.62	285.65	97.15	33.10		284.40	306.62	198.15	98.02
2	348.96	388.49	37.87	54.28		487.99	365.57	272.33	91.15
3	393.23	271.79	47.52	75.62		360.37	300.46	154.15	137.66
4	239.67	245.42	40.01	33.96		206.86	142.44	103.27	130.16
5	222.84	278.75	96.66	31.89		317.53	316.34	112.44	41.81

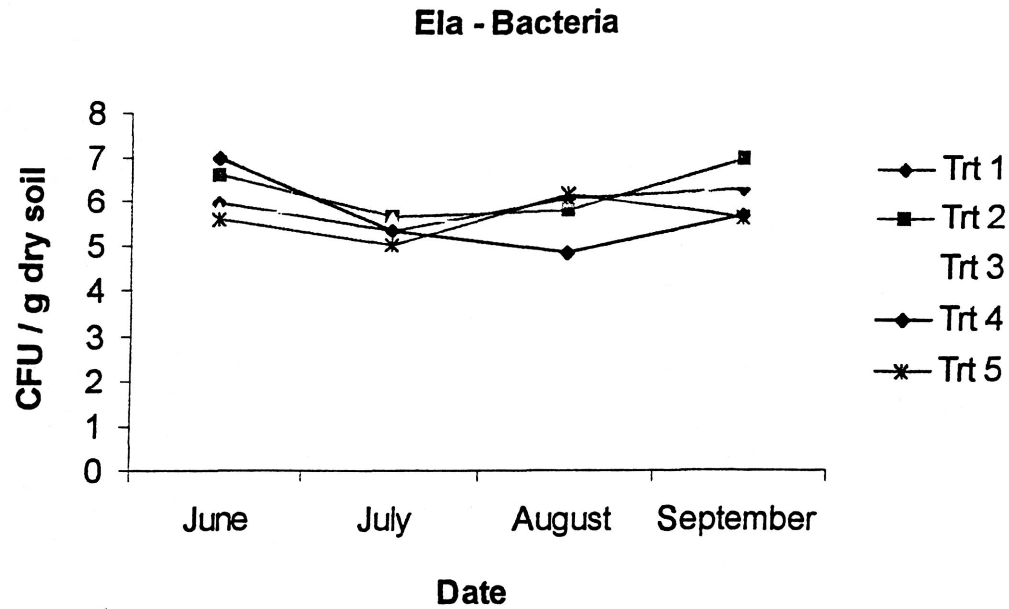
Table 2.0 Colony Forming Units per gram of dry soil. Numbers represent average of five samples for each treatment.

		Site 1					Site 2		
		Ela					Kropp		
Treatment	Date 1	Date 2	Date 3	Date 4		Date 1	Date 2	Date 3	Date 4
1	5.95	5.31	6.04	6.25		7.03	6.32	5.82	6.03
2	6.59	5.63	5.75	6.94		6.51	6.15	5.91	6.32
3	5.83	5.57	5.39	6.40		6.11	5.43	6.89	5.89
4	6.98	5.31	4.81	5.62		6.28	6.01	6.28	5.88
5	5.56	4.99	6.16	5.60		6.35	5.97	6.16	5.79




Ela - Fungi
600
500
400
300
200
100
0
Hyphae (m) / g dry soil
June
July
August
September
Date
Trt 1
Trt 2
Trt 3
Trt 4
Trt 5


Kropp - Bacteria
8
7
6
5
4
3
2
1
0
CFU / g dry soil
June
July
August
September
Date
Trt 1
Trt 2
Trt 3
Trt 4
Trt 5



DISCUSSION

These results represent only one year of data collection, and hence, any conclusions made at this time are only preliminary. It is our desire to repeat this study in 2001, with soil sampling beginning in April and concluding in September. The study would begin earlier in the growing season for 2001 because it is important to determine microbial biomass early in the growing season, as this is the time when the trees are beginning to sequester nutrients. Plant nutrient sequestration is intimately linked with microbial activity, and hence, enumeration of their numbers can provide valuable insight into the controls governing early season nutrient cycling.

For the 2000 growing season, the results suggest that in the Kropp site, bacterial biomass has been enhanced in comparison to the Ela site. The differences in biomass may be due to the longer period of time that the Kropp site has been under organic management; transitional in 1995, certified organic in 1998. In comparison, the Ela site is currently in the transitional phase. While there was no significant treatment effect in either of the sites, the above mentioned results are exciting because they indicate that organic management practices (applied over the long-term) have the potential to increase bacterial biomass. Again, as bacteria are key players in belowground nutrient cycling, their numbers can be indicative of potential aboveground plant response.

Furthermore, the results suggest that increased fertilizer (chicken manure or compost) application does not directly translate into increased microbial biomass. It would be valuable to measure aboveground plant growth to see if increased fertilizer application results in increased annual growth. If this were found to be the case, one could justify increased fertilizer application rates. However, if the aboveground response were similar to the belowground response (no significant difference between treatments), increased fertilizer application would prove to be an unnecessary cost.

In summary, the results from this study are potentially very exciting as they suggest that increased fertilizer application does not lead to increased microbial biomass. If these results can be confirmed by a second year of data collection, the results will provide evidence to suggest that our current paradigm of thinking about fertilizer application is perhaps incorrect. In perennial agroecosystems, the key to nutrient cycling may be to obtain a proper ratio of bacteria to fungi. When such a ratio is obtained and the system is not subjected to repeated disturbance, the soil biota are capable of retaining and cycling nutrients, making them available at critical times of plant growth. If this state is achieved, only minimal, or perhaps no, additional applications may be necessary. This would allow growers to reduce costs associated with fertilizer application.

OUTREACH:

Pending the funding of this project for a second year, the results from this study will be written up and submitted to the *Journal of Applied Soil Ecology.* Additionally, an article reviewing the study will be submitted to the Fruit Growers Newsletter.

LITERATURE CITED:

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FUNDING SOURCES:

This research project was supported by a grant from SARE Farmer/Rancher (USDA) and Gerber Products Company.