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APPLICATION OF ANIMAL MANURE/COMPOST IN AN IRRIGATED OAT/CORN ROTATION

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Abstract: *This study was initiated to determine the biological and nutrient impacts of manure and compost applications on an oat/corn rotation in Central Arizona. Bacterial analysis for E.Coli, Listeria and coliphage and nutrient analysis for nitrogen, phosphorus and electroconductivity were conducted on soil, manure/compost, irrigation water, drainage water and plant samples. The presence of endocrine disruptors was also tested on the irrigation and drainage water. After a single season of oats, there doesn't appear to be any significant increase in the presence of bacteria in the soil-water-plant environment. Endocrine disruptors were detected in drainage and irrigation water samples. Nitrate leaching is occurring but at relatively low rates. Oat forage yields between treatments were all over 10,000 kg/ha and there was no statistically significant difference between them.*

Keywords: Manure, irrigation, oats, corn, drainage lysimeter, bacteria, nitrate, phosphorus

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INTRODUCTION

The recent CAFO (Confined Animal Feeding Operation) ruling by the EPA presented some new challenges for owner/operators of CAFOs and their management of animal waste on the farm. In addition to waste handling and permit requirements, the new rule requires that animal waste application to land on CAFOs must not exceed the plant's uptake and/or the soil ability to hold the nutrients in the waste. Two nutrients, phosphorus and nitrogen, have been identified as key elements in which this balance must be maintained. Phosphorus is important because overloading of phosphorus on agricultural fields can cause excessive phosphorus loss through runoff from the field. Nitrogen has also been identified as a key component because excessive loading of nitrogen can cause nitrate leaching and contamination of groundwater.

In most states, phosphorus has been used as the limiting element. However, phosphorus is more problematic in areas where there is surface water. Excessive levels of phosphorus in surface waters can cause eutrophication, a process by which the surface water becomes over populated with algae. The algae eventually dies, which consumes the dissolved oxygen in the water and the lake or pond eventually becomes uninhabitable for fish or other marine life.

In Arizona, since surface water is scarce, it was decided by the Natural Resource Conservation Service (NRCS) that the limiting nutrient for animal waste applications would be nitrogen. Therefore, CAFO owners were restricted to apply only the amount of nitrogen that the plant would uptake and that the soil would hold. Unfortunately, there was little data on how to manage animal waste applications and assure that nitrate leaching was minimized and plant growth was optimized. Thus, a grant from the Arizona Department of Environmental Quality (ADEQ) helped to fund research to develop Best Management Practices for animal waste applications in Arizona.

A more comprehensive literature review can be found in the companion paper by Tanksley and Martin (2003).

METHODOLOGY

The site selected for the research was a site that had been used for a previous animal waste application study involving alfalfa (Tanksley and Martin, 2003). The site was located at the south end of the University of Arizona Maricopa Agricultural Center. The soil type was a Casa Grande sandy clay loam, a fine-loamy, mixed, hyperthermic Typic Natrargids. The field was approximately 1 hectare in size. Each plot was 6.7 m wide and 138 m long. A field plot plan is shown in Figure 1.

Rep 1			Rep 2			Rep 3			Rep 4		
P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
T2	T1	T3	T3	T2	T1	T1	T3	T2	T2	T1	T3
⊕	□	⊕	⊕	□	⊕	⊕	□	⊕	⊕	⊕	⊕

T1= Inorganic N; T2=Compost; T3=Manure; ⊕ = Suction Lysimeter; □ = Drainage lysimeter.

Figure 1. Plot layout of corn receiving manure, compost, and inorganic fertilizer treatments where the top of the page represents north.

It was decided that samples would be tested for three common bacteria often found in animal waste: *Escherichia coli* (*E. Coli*), *Listeria* and coliphage – a virus of bacteria linked with *Salmonella*. Elemental analysis would include nitrogen and phosphorus. Also, electroconductivity would be measured to assess any salt accumulation. Finally, estrogenic activity would be evaluated. Estrogenic activity is an indication of the presence of endocrine disruptors that have been linked to the disruption of the reproduction of fish species.

Soil Sampling

Prior to any field activity, soil samples were taken to provide a baseline for the study. The soil sampling was conducted over a period of two days. On day one, October 7, 2002, samples were taken from the first six plots. Using a plastic tube liner inserted into a Giddings probe soil sampler, samples were taken for microbial analysis (Fig. 2). The inserts allowed for a clean, non-contaminated 60 cm sample to be taken. These samples were taken at three locations in the plot, approximately at 1/4, 1/2, and 3/4 distance down the field. The plastic insert, once filled with soil, was capped at both ends and placed on ice. Between samples, the probes (which the plastic liners were inserted into) were disinfected with chlorine and rinsed with sodium thiosulfate. The microbial sampling was completed by 10:00 AM and the samples were rushed to a microbiology lab in Tucson (Fig. 3). Once there, the plastic tubes were cut into three sections: 0-15, 15-30 and 30-60 cm (Fig. 4). The cutting tools were disinfected between cuttings by dipping them in alcohol and flaming them (Fig 5). Once the samples were cut, sub-samples were taken and analyzed within 48 hours. This was repeated the second day, October 8, 2002, for the remainder of the plots.

To analyze the soil for nitrogen (N), phosphorus (P) and electroconductivity (EC), a separate set of samples were taken. Again, the Giddings probe soil sampler was used but without the plastic inserts. Samples were taken in the afternoon of the days when the microbial samples were taken.

These samples were separated into 9 sections: 0-15, 15-30, 30-45, 45-60, 60-90, 90-120, 120-150, 150-180 and 180-210 centimeters.



Figure 2. Plastic insert used for sampling the soil for biological analyses.



Figure 3. The soil tube filled with soil at the lab in Tucson.



Figure 4. Cutting the tube into 15 cm sections.

Field preparation and planting

The field was sprayed with Roundup on November 4, 2002 to kill off any remaining alfalfa from the previous study. On November 12, the manure and compost was applied. Test results from the analyses (Table 1) showed that the manure contained approximately 14,300 ppm nitrogen and the compost contained approximately 13,800 ppm nitrogen. The variety of oats chosen was Cayuse. This variety has been grown in Arizona for several years and is one of the highest in forage yields with an average of about 10,680 kg/ha (Sheedy et al., 1989a, 1989b, 1990a and 1990b). Utilizing the nutrient report summary from the USDA NRSC Crop Nutrient Tool (<http://npk.nrcs.usda.gov/>) for common oats, 10,680 kg would remove 187 kg/ha of nitrogen. Therefore, we selected 200 kg N/ha as our target application.

Table 1. Nitrogen and Phosphorus analyses of compost and manure samples applied to the oat crop in November 2002. All values are in ppm.

Sample	Organic N	Ammonium N	Total Kjeldhal	Nitrate N	Total N	PO4 - P	EC (TDS)
Manure 1	14623.8	369.76	14993.56	10.08	15003.64		
Manure 2	12564.73	2718.44	15283.17	8.88	15292.05		
Manure 3	12099.38	493.64	12593.02	3.48	12596.5		
Average	13095.97	1193.95	14289.92	7.48	14297.4	2520	35360
Compost 1	12700.57	56.56	12757.13	1312.56	14069.69		
Compost 2	11171.37	66.92	11238.29	1452.24	12690.53		
Compost 3	13243.4	44.68	13288.08	1287.56	14575.64		
Average	12371.78	56.05	12427.83	1350.79	13778.62	643	23200

This inferred that we needed apply 2380 kg of manure and 2465 kg of compost per plot in order to apply 200 kg N/ha. Although the manure spreader had been calibrated, it was difficult to applied exact amounts. The actual amount applied was 2320 kg of compost per plot and 2880 kg of manure per plot. As the manure and compost were spread, weights were taken to determine the exact amount applied (Figs. 5-7).

Immediately following the application, the manure and compost were disked into the soil using a traditional disk plow. The plow was brushed down between plots to remove any excess soil so as not to cross-contaminate the treatments. Additionally, the inorganic treatment plots received 30 kg/ha of 11-55-00 fertilizer that was also disked in. On November 13, 2002, the field was planted at a rate of 80 kg of seed/ha. On November 15, 2002, the field was irrigated with 10 cm of water. Another 10 cm were applied on November 27, 2002, to loosen the soil and help with emergence.



Figure 5. The spreader being loaded.



Figure 6. The manure spreader being weighed.



Figure 7. The compost being spread onto the field.

Soil Water Sampling

Soil water samples were obtained using two methods. The first was leachate from drainage lysimeters previously installed in the field (Martin et al., 1999). The drainage lysimeters (2m x 1.5m x 1.8m) were located in three plots, one having treatment 1, one with treatment 2 and the other with treatment 3 (Fig. 8). The treatment assignments were similar to the previous study, i.e. Lysimeter 1 was previously the no-nitrogen treatment, Lysimeter 2 was the compost treatment and Lysimeter 3 was the manure treatment. In this study, the no-nitrogen treatment (Lysimeter 1) was replaced with the inorganic nitrogen treatment.

Samples from the drainage lysimeters were taken for bacterial, estrogenic and nutrient analyses. In addition to the three drainage lysimeters, suction lysimeters were installed in the other plots. Samples from these lysimeters were analyzed for nitrate content only because the screen in which the water needed to pass through often destroys bacterial cells and an estrogenic protocol had not yet been established.

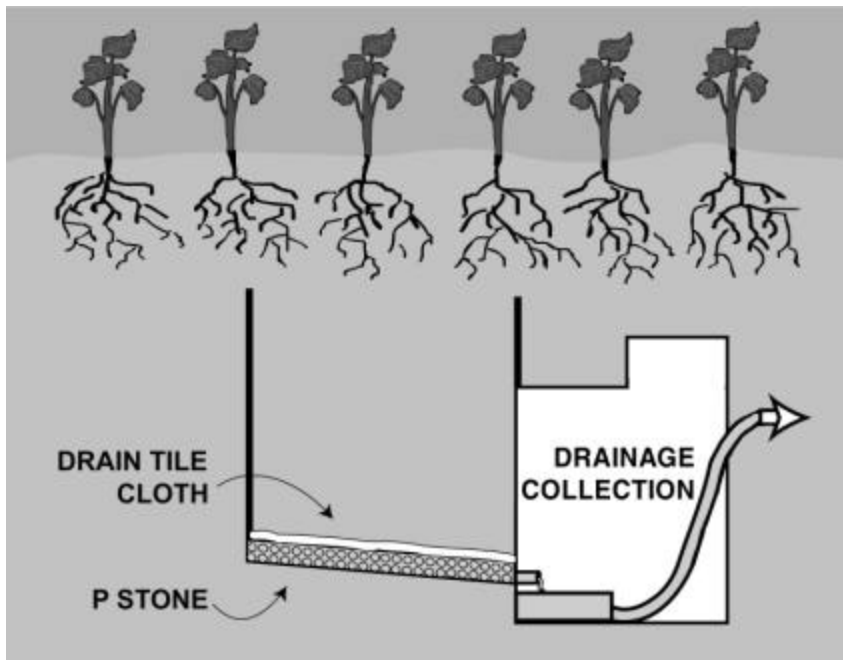


Figure 8. Schematic of the drainage lysimeter system. The lysimeter and drainage collection system consist only of stainless steel material.

RESULTS AND DISCUSSION

Oat Yield

The oat yield data are shown in Figure 9. All three treatments yielded over 10,000 kg/ha of forage. Although there are slight differences between treatments, none of them are statistically significant.

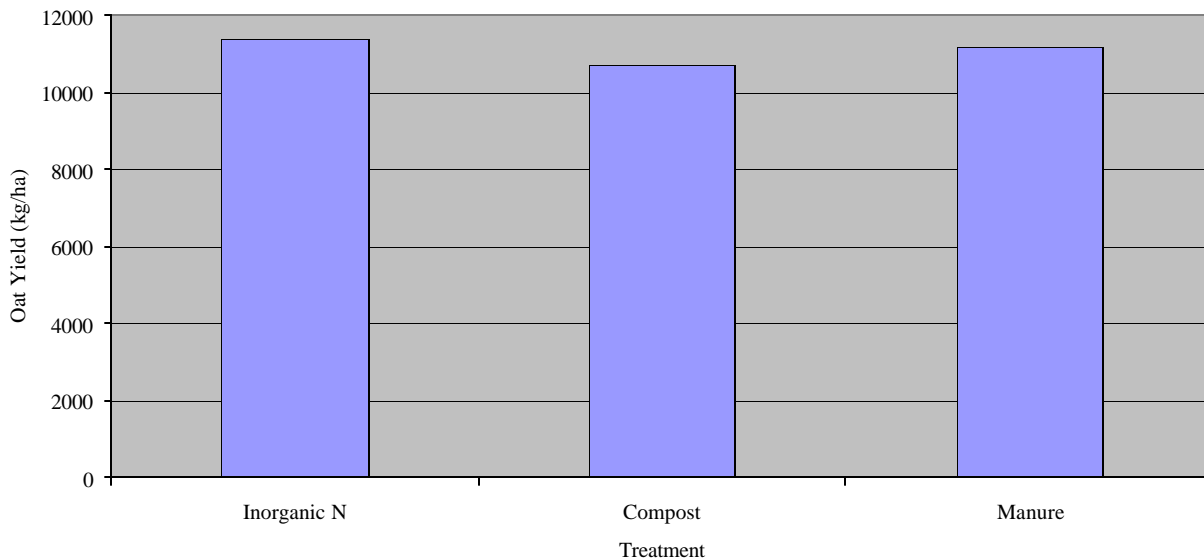


Figure 9. Oat forage yield for the manure study 2002-03. Maricopa, AZ.

Bacterial Analyses

Soil Analysis

The initial soil sampling showed that the all plots contained *E. Coli* and some coliphage. However, *Listeria* was not present in the any of the soil samples. The *E. Coli* and coliphage may have come from the previous manure/compost treatments for those plots but must have been either present in the soil or added through the irrigation water in the inorganic N plots.

Soil Water and Irrigation Water

The drainage lysimeter and irrigation water were analyzed for presence of bacteria. The analyses showed no *Listeria* in either the drainage or irrigation water. Two irrigation water samples tested positive for *E. Coli* and 1 drainage sample was positive. Several samples of the irrigation water did test positive coliphage, as did the drainage samples.

Manure/Compost

Analysis of the manure and compost revealed that both had *E. Coli* and coliphage present but *Listeria* was not detected. *E. Coli* was higher in the manure but coliphage was higher in the compost. A summary can be found in Table 2.

Plant Samples

Plant samples were taken to assess any bacterial contamination of the crop. Only the bottom 10 cm were sampled since this is the area where bacterial contamination is most likely to occur. Only one sample, a compost plot sample, showed positive for *E. Coli* (data not shown). All of the other samples were negative for *E. Coli*. Additionally, all samples tested negative for *Listeria* and coliphage.

Table 2. Bacterial results of the manure and compost applied to the oat crop, November 2002.

Sample Type	Coliform (Per g of material)	<i>E.Coli</i> (Per g of material)	Coliphage (MS-2) (Plaque Forming Unit g of material)	<i>Listeria</i> (Per g of material)
Manure	>7330.9	45.75	30.3	Negative
Compost	185.4	<3.0	652	Negative

Estrogenic Activity

Soil Analysis/Manure and Compost

No protocol has yet been established within our budget to analyze the soil and/or the manure and compost for estrogenic activity.

Soil Water and Irrigation Water

Original data for the 2003 sampling events are shown in Figures 10 through 13, respectively. Deflection of the sample curves downward from horizontal indicates presence of estrogenically active compounds, which occurs in these samples at higher fractions of sample in the assay mixture. The samples labeled as "UPH2O" and "EtOH" in the figures are negative controls. Results indicate that estrogenic activity is consistently detected in the lysimeter samples. The irrigation canal water (Figures 11 and 12) is less estrogenic, indicating addition of compounds exhibiting estrogenic activity during percolation of the water to the lysimeters.

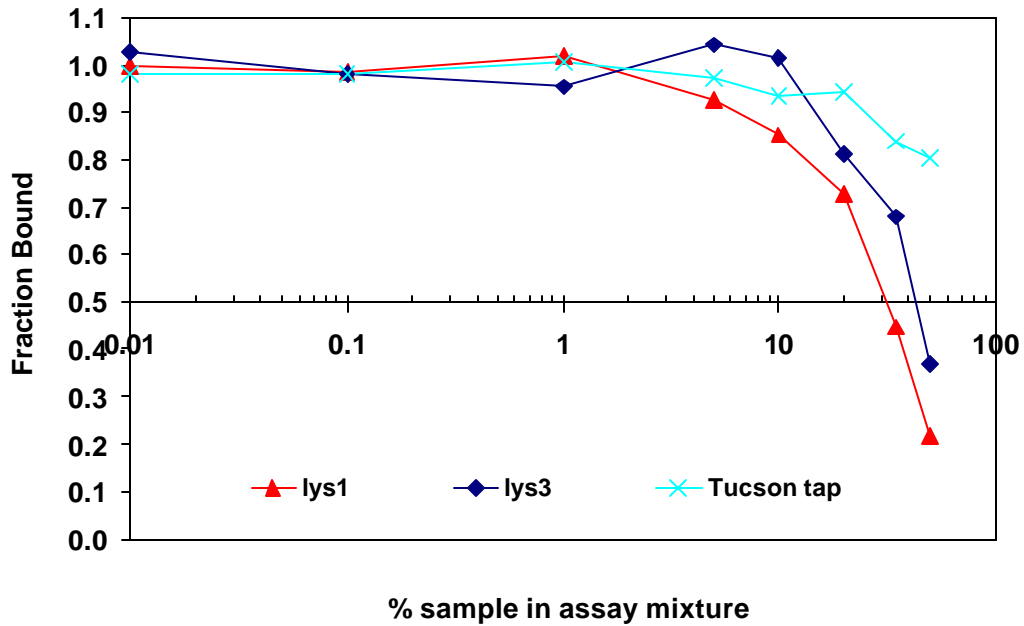


Figure 10. Estrogenic activity for MAC samples, January 2003.

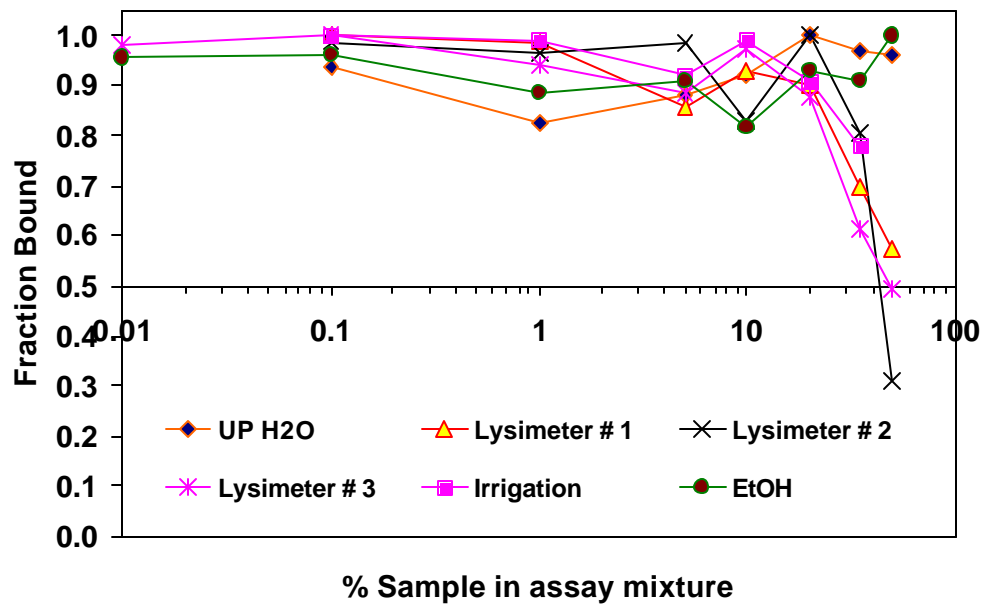


Figure 11. Estrogenic activity for MAC samples, February 2003.

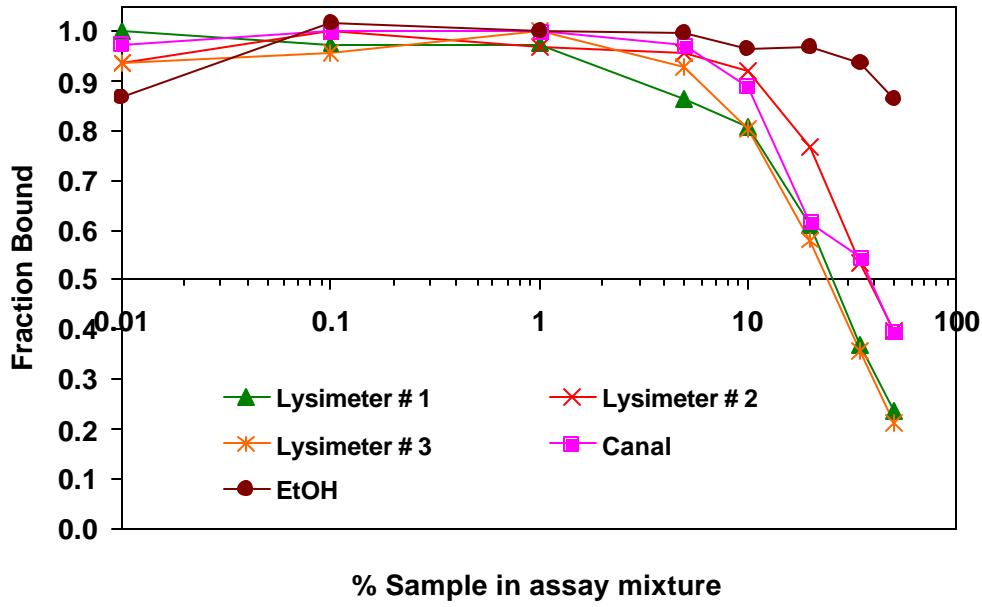


Figure 12. Estrogenic activity for MAC samples, March 2003.

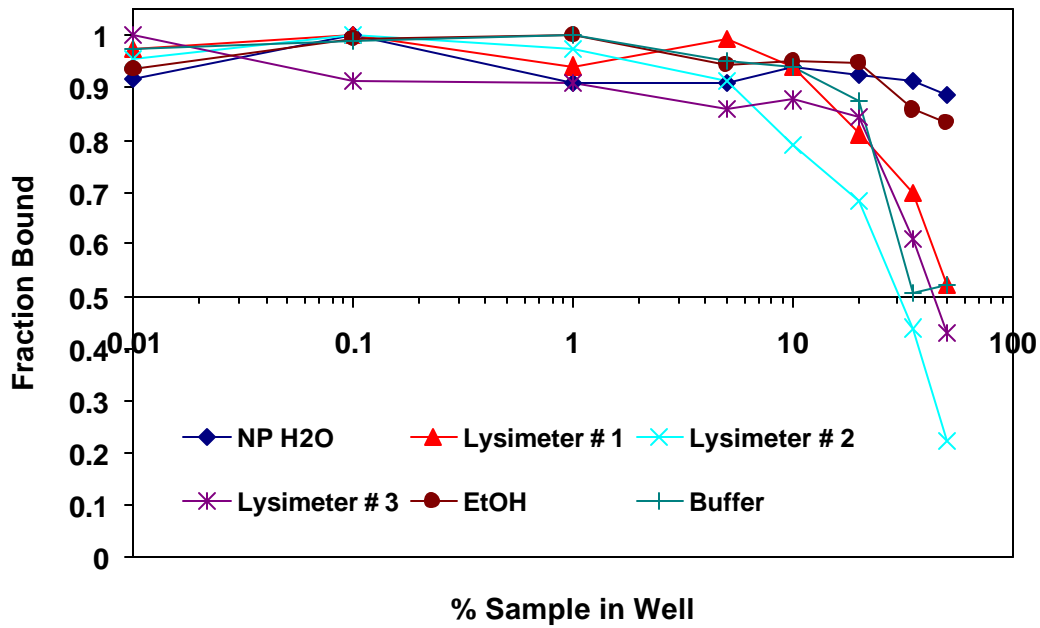


Figure 13. Estrogenic activity for MAC samples, April 2003.

Nutrient Analyses

Soil

Initial soil tests showed that the manure and compost plots had higher levels of nitrogen and phosphorus in the top 210 cm of soil (data not shown). This was mainly due to the compost and manure applications from the previous study. Another set of soil samples will be taken at the end of the study.

Soil Water and Irrigation Water

The drainage data from the three drainage lysimeters is shown in 14. Although the compost lysimeter seems to be draining less, the difference is only 8 cm. The nitrate leaching data (Fig. 15) followed a similar pattern. Data from the suction lysimeters has not yet been analyzed.

Irrigation water was also tested for nitrate levels. Levels ranged from 2-7 ppm NO₃-N (data not shown).

Manure/Compost

The manure and compost data can be found in Table one. The nitrogen data show that the manure and compost had relatively the same total N content. However, the manure was higher in ammonium and the compost was higher in nitrates. Also, the P level in the manure was almost 4 times that of the compost and the EC was also higher.

CONCLUSION

This is only the first season of the two-year study and there is still much left to investigate. However, the estrogenic data suggests that there may be some interaction between the soil and the irrigation water and that the soil vadose may act as a filter as well as a catalyst.

Bacterial analyses suggest that we may have a residential presence of *E. Coli* in the soil and in the irrigation water. Further tests and analyses will be required.

The nutrient analyses show a definite movement of nitrate through the soil. However, it is still too early to delineate one treatment from the other.

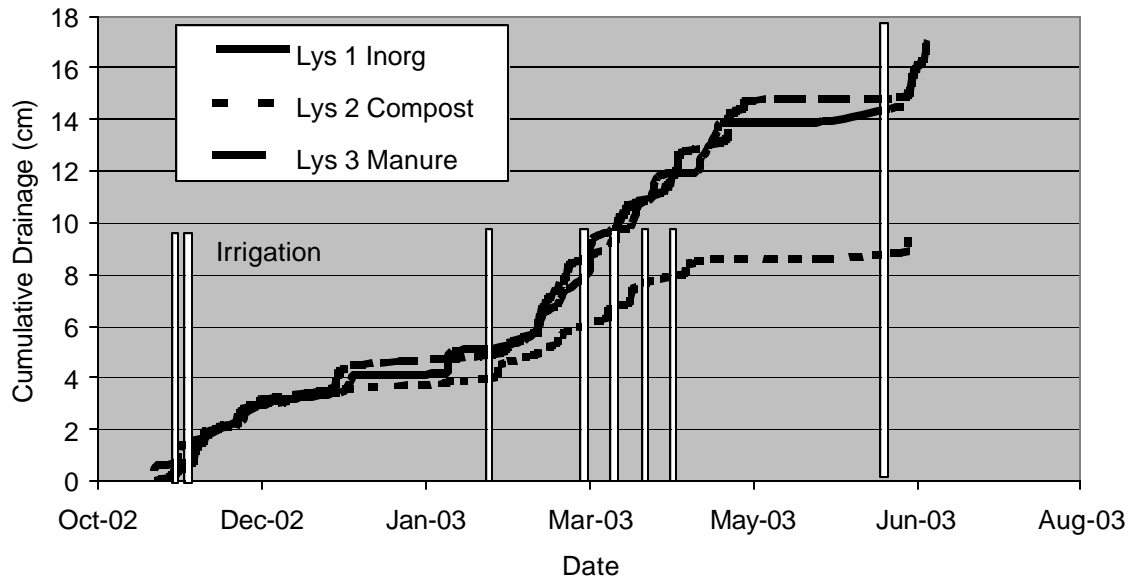


Figure 14. Drainage from the three drainage lysimeters for the oats/corn manure study for 2002-03. Maricopa, AZ

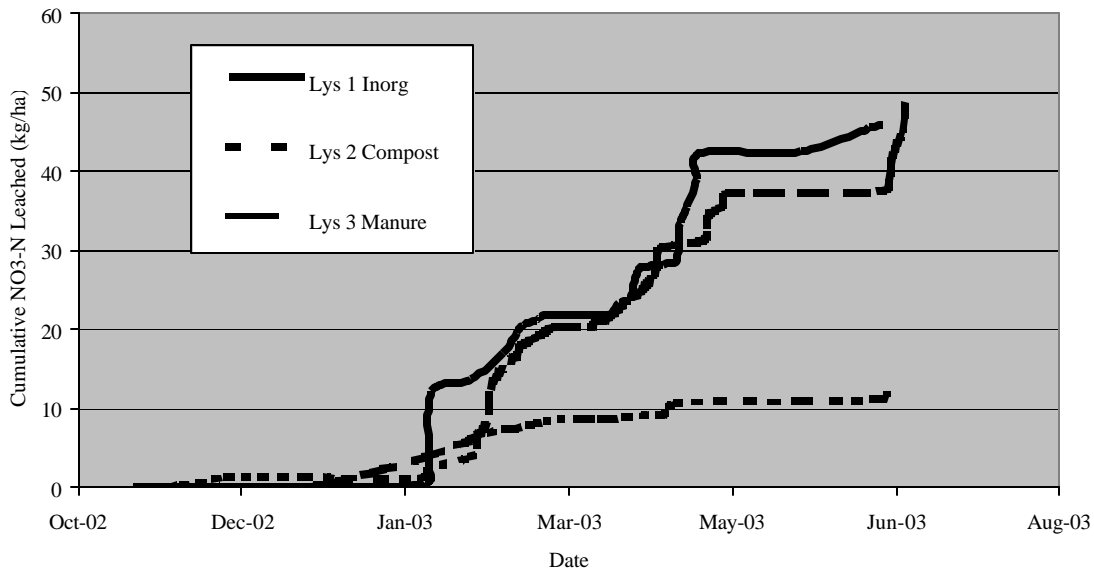


Figure 15. Nitrate leaching data from the three drainage lysimeters for the oats/corn manure study for 2002-03. Maricopa, AZ

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