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III. NON-TECHNICAL SUMMARY

Title: Environmental Impacts of the Use of Poultry Manure for Agricultural Production Systems

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With the recent expansion in poultry production nationwide and its potential environmental impacts, poultry operations have been under greater public scrutiny than in the past. More than six billion broilers are raised in the U.S.A. each year and produce more than nine million tons of manure. In May of 1997, Iowa ranked 4th nationally in layer production behind Ohio, California, and Indian. Rapid and concentrated growth in the poultry industry has increased the concern about non-point source pollution. Very often, the local agricultural lands, located near the poultry houses, become disposal sites for large quantities of litter. From non-point source pollution standpoint, water quality parameters of greatest concern are nitrate-nitrogen (NO_3-N), phosphate-phosphorus (PO_4-P), and pathogen bacteria. Each of these parameters, present in the poultry manure, has the potential to pollute surface and ground water.

In 1998, the Leopold Center for Sustainable Agriculture and Iowa Egg Council jointly funded this study to investigate the effects of poultry manure application on surface and groundwater quality. In this study, experiments were conducted using six field lysimeters (2.28 m long by 1.5 m wide and 0.91 m deep) and ten 0.4 ha plots located at the Agronomy and Agricultural Engineering Research Center near Ames, Iowa. These lysimeters and field plots are fully instrumented, each with a single tile line and a sump to collect shallow ground water samples for water quality analysis. Two field plots are instrumented with H-flumes to collect surface water samples for water quality analysis. Poultry manure was obtained from Farm Egg Products, Humboldt, IA. Field plots and lysimeters were given applications of poultry manure to give N application rates of 168 and 336 kg-N/ha for the corn crop under corn-soybean production system. For comparison purposes, commercial N fertilizer (UAN) was also applied to four plots to give N application rate of 168 kg-N/ha. In December 1999, one more sump was installed to intercept a tile line from a plot, which did not receive any manure or UAN fertilizer for the past five years. This plot will be sampled for water quality in 2000. Water quality data on NO_3-N, PO_4-P, and bacteria were collected from tile drains and H-flumes in 1998 and 1999 to observe the effects of poultry manure on water quality. These data will be used to develop crop and soil management practices for managing poultry manure for agricultural sustainability and enhancing water quality. At this stage of this study, we have field data for 1998 and 1999 cropping seasons. Water quality data from this study for 2000 would be needed before we develop final conclusions on the impacts of poultry manure on surface and ground water quality.

The results of this study indicate that plots and lysimeters treated with 168 kg-N/ha from poultry manure resulted in the lowest NO_3-N and PO_4-P concentrations and losses with tile water in comparison with plots and lysimeters treated with 168 kg-N/ha from UAN or 336 kg-N/ha from poultry manure. Also, plots treated with 336 kg-N/ha from poultry manure resulted in high fecal coliform concentrations in the tile water when compared with the other treatments.

IV. TECHNICAL REPORT

A. DISCUSSION OF PRELIMINARY FINDINGS

This report presents results from two years (1998 and 1999 cropping seasons) of study using water quality data from lysimeter and field plot experiments. Figure 1 shows the rainfall pattern at the experimental site during the 1998 and 1999 growing seasons. This figure shows that in 1998 highest amount of rainfall occurred in the month of June. In 1999, there was an even distribution of rainfall from April through August. The average annual rainfall for the Ames site is about 810 mm (31.9 inches). About 885 and 864 mm of rainfall fell in 1998 and 1999, respectively. Table 1 gives the chemical analysis of poultry manure used for this study. The results of poultry manure analysis indicate that we ended up in applying much higher rates of P at 168 and 336 kg-N/ha from poultry manure.

Lysimeter Experiments

Six lysimeters used in this experiment are small boxes (2.28 m long x 1.5 m deep x 0.91 m wide) that were installed in the field in 1992. The following discussion of results is based on the data collected from lysimeters in the 1998 and 1999 growing seasons. The data presented in Table 2 show that during both seasons, lysimeters treated with 168 kg-N/ha or 336 kg-N/ha from poultry manure produced significantly higher corn yields in comparison with yields from lysimeters treated with UAN fertilizer. However, in 1998, corn yields from lysimeters were lower than normal because the corn plants had to be transplanted resulting in some stressed growth at the beginning of the growing season. On the average, the data show that higher corn yields were obtained in 1999 compared with 1998.

The data in Table 3 show that during both years, application of poultry manure to lysimeters had no significant effect on the quality (in terms of protein, starch, fiber, density, and oil content) of corn-grains. However, these results show that in 1999 starch content in corn grains from lysimeters was higher (not significant) compared with the results of 1998. Analysis of N content in corn stalks indicated that there were no significant differences in concentrations of N in corn stalks from all treatments. However, plant stalk samples taken from lysimeters treated with 336 kg-N/ha from poultry manure had relatively higher N concentrations (not significant) in comparison with other N treatments.

Analysis of soil samples for NO_3-N concentrations indicates a large variability between treatments for both before planting and after harvesting (Table 3). As expected, the concentrations of NO_3-N in the topsoil layers were higher when compared with the lower layers. The concentrations of NO_3-N in the soil decreased between planting time in 1998 and harvesting time in 1998. After harvesting, the concentration of NO_3-N in the lower soil layers appears to have started building up.

Figure 2 shows that high rainfall amount during both years produced high subsurface drainage water from lysimeters. The data presented in Table 4 show that in 1998, there were no significant differences in the amount of drainage water from lysimeters. In 1999, lysimeters treated with 168 kg-N/ha from poultry manure produced relatively lower amount of subsurface drainage water when compared with the other treatments. Figure 2 shows that most drainage from lysimeters occurred in June 1998 and between April and June of 1999. On the average, higher total subsurface drainage water was observed in 1999 in comparison with 1998 because of larger amount of rain water between April and August in 1999. These results also show that higher subsurface drainage flows resulted in lysimeters in comparison with field plots. This was due to the fact that no surface runoff occurred in the lysimeters and lysimeters were sealed at the bottom to allow most of the drainage water get collected in the sumps.

Table 5 and Figure 3 show that in 1998, lysimeters treated with UAN fertilizer or 336 kg-N/ha from poultry manure resulted in significantly higher NO_3-N concentration in subsurface drainage water in comparison with lysimeters treated with 168 kg-N/ha from poultry manure. Lysimeters treated with 168 kg-N/ha from poultry manure consistently produced NO_3-N concentration less than 10 mg/L during both seasons. Figure 3 shows that NO_3-N concentrations in drainage water increased between May and July 1998. This was due to the fact that the manure needed time to mix with the soil and also for N to be mineralized before being leached down by the percolating water.

The results given in Table 4 and Figure 4 show that in 1998, lysimeters treated with UAN fertilizer or 336 kg-N/ha from poultry manure produced significantly higher NO_3-N losses with subsurface drainage water when compared with lysimeters treated with 168 kg-N/ha from poultry manure. The high N loss from UAN treatment was due to the fact that N from UAN fertilizer is highly soluble and thus, easily leached out with water. During the second year of application, higher losses of NO_3-N were observed from lysimeters treated with 336 kg-N/ha from poultry manure compared with the first year. The high NO_3-N losses from high poultry manure application rate suggest that N was applied in excess of plant requirements. These results are consistent with those of Kingery et al. (1993) and Wood et al. (1996), who found that pasture and corn receiving high long-term applications of poultry manure had high concentrations and loss of NO_3-N with drainage water. The higher NO_3-N concentrations (greater than 10 mg/L) in drainage water indicate a high pollution potential of water resources with NO_3-N from plots treated with either UAN fertilizer or high poultry manure application rate.

Data presented in Table 4 and Figure 5 show that in 1998, lysimeters treated with UAN fertilizer gave higher average PO_4-P concentrations in comparison with lysimeters treated with poultry manure. Figure 6 shows that in May 1999, lysimeters treated with 336 kg-N/ha from poultry manure gave higher PO_4-P concentrations when compared with other N treatments. In August, the concentration of PO_4-P in drainage water from lysimeters treated with 168 kg-N/ha from UAN fertilizer were higher in comparison with the poultry manure treatments. In the other months, there were no significant differences between N-treatments. The overall average indicate that UAN treatments produced higher PO_4-P concentration than poultry manure treatments.

The data in Table 4 and Figure 6 show that in 1998, lysimeters treated with UAN fertilizer gave the highest PO_4-P losses when compared with the manure treatments. Very high PO_4-P losses occurred in June due to the high rainfall and drainage flow. In 1999, lysimeters treated with UAN fertilizer or 336 kg-N/ha from poultry manure produced higher PO_4-P loss in comparison with lysimeters treated with 168 kg-N/ha from poultry manure. Figure 6 also shows that in May of 1999, lysimeters treated with 336 kg-N/ha from poultry manure produced higher PO_4-P loss when compared with other treatments.

The results in Table 5 show that in 1998, lysimeters treated with 336 kg-N/ha from poultry manure produced high average concentrations of fecal coliform bacteria in comparison with the other treatments. All samples from lysimeters treated with 168 kg-N/ha from poultry manure had fecal coliform densities less than 200 cfu/100 ml throughout the 1998 season. The results also show that in April 1999 (before manure application), lysimeters treated with poultry manure produced high fecal coliform counts. This was attributed to background contamination levels from previous year's manure. In May and June, fecal coliform counts from all treatments were less than 200 cfu/100 ml. In the month of July, all treatments produced fecal coliform counts greater than 200-cfu/100 ml. The data indicate a high pollution potential of subsurface water with fecal coliform bacteria towards the end of the season. These results indicate that a high application rate of poultry manure may result in pollution of water resources with fecal coliform bacteria in comparison with the application of UAN fertilizer or lower rates of poultry manure. The presence of mice in the plots could have contributed to the high counts of fecal coliform bacteria in subsurface drainage water from non-manured plots (Schepers and Doran, 1980) or due to the build up of stable bacterial populations in the soil (Smallbeck and Brommel, 1975; Faust, 1982).

The data presented in Table 5 show that in 1998, lysimeters treated with 336 kg-N/ha from poultry manure resulted in higher counts of fecal streptococcus in subsurface drainage water in comparison with lysimeters treated with UAN or 168 kg-N/ha from poultry manure. In May and July 1999, lysimeters treated with 168 kg-N/ha or 336 kg-N/ha from poultry manure produced higher fecal streptococcus counts in drainage water when compared with lysimeters treated 168 kg-N/ha from UAN.

The data in Table 5 also shows that in June 1998, lysimeters treated with 336 kg-N/ha from poultry manure resulted in the highest counts of *E. coli* in subsurface drainage water when compared with the other treatments. In June 1998, *E. coli* counts in drainage water from all treatments were mostly greater than 200-cfu/100 ml, while in May, there were no significant differences between treatments. The results also show that densities of *E. coli* from all treatments were high in April 1999 (before manure application) and very low (less than 200 cfu/100 ml) for the rest of the season. The high concentrations in April could be due to cross contamination from last year's manure and/or the presence of ground animals.

Field Plot Experiments

Following discussion is based on data collected from eight 0.4 ha plots during the 1998 and 1999-growing seasons. It is apparent from Table 6 that even though no N was applied to the soybean subplots, soybean yields were good for all treatments including the check plot during both years. These results show that in 1998, no significant differences in soybean yields were observed among treatments. Similar results were obtained in 1999. The average corn yields for the state of Iowa in 1998 and 1999 were 9.22 and 9.48 Mg/ha, respectively. The results in Table 6 show that in both years, corn yields from plots treated with poultry manure were as good as the state averages. Corn yields from plots treated with poultry manure were also significantly higher when compared with yields from check plots or plots treated with UAN fertilizer.

The data in Table 7 show that during both years, application of poultry manure to plots had no significant effect on the quality (in terms of protein, starch, fiber, density, and oil content) of soybeans and corn-grains. However, the results show that in 1999 protein content in soybeans were higher (not significant) when compared with the 1998 results. The oil content of soybeans were lower in 1999 than in 1998. Corn stalks from plots treated with 336 kg-N/ha from poultry manure had significantly higher N concentrations in stalks when compared with the other treatments. This was due to the fact that excessive application of poultry manure results in excess N in the soil than the crop would need. The low N content in the stalks from other N treatments could mean that corn plants had inadequate N availability resulting in removal of N from cornstalks and leaves during the grain-filling period and consequently resulted in lower yields (Blackmer and Mallarino, 1997).

Analysis of soil samples for NO_3-N concentration indicates a lot of variability between treatments both before planting and after harvesting (Table 8). As expected, the concentration of NO_3-N in the topsoil layers was higher in comparison with the lower layers. The results presented in Table 8 also indicate that soil NO_3-N concentrations from all plots increased between the time of harvest in 1998 and the time of planting in 1999. This is due to the absence of crops and almost zero NO_3-N leaching or runoff losses during the winter months.

Table 9 and Figure 7 show that during both seasons, plots treated with poultry manure produced lower amounts of subsurface drainage water in comparison with plots treated with UAN fertilizer. Figure 7 shows that subsurface drainage flow followed the rainfall pattern during the two seasons. However, in some months, there was no corresponding tile flow due to low soil moisture content. Although slight differences in topography existed from plot to plot, a large part of the variation in total flow from plots could also be due to subsoils with different hydraulic conductivities. Variable conductivities would affect the proportion of percolating water intercepted by the tile drains and could also result in the drainage area being different from that assumed. Four and five runoff events occurred in 1998 and 1999, respectively. Runoff data showed that there were no significant differences in runoff amount from the two poultry manure treatments. The low surface runoff from plots was due to high infiltration rate of the soil and the gentle slope of the area (less than 1%).

Table 9 show that in both 1998 and 1999, plots treated with 168 kg-N/ha from poultry manure or UAN fertilizer gave significantly lower NO_3-N concentrations in subsurface drainage water in comparison with plots treated with 336 kg-N/ha from poultry manure. Figure 8 shows that all treatments (except in March 1998 for plots treated with 168 kg-N/ha from poultry manure) produced average NO_3-N concentrations greater than 10 mg/L in all the months. Plots treated with 336 kg-N/ha from poultry manure produced significantly higher average concentration of NO_3-N in drainage water in comparison with plots treated with UAN fertilizer or 168 kg-N/ha from poultry manure.

The data presented in Table 9 show that during both seasons, there were no significant differences in NO_3-N concentration in runoff water from the two poultry manure treatments. However, in 1998, the average concentrations of NO_3-N in runoff water were greater than 10 mg/L while in 1999 they were less than 10 mg/L for both manure treatments.

The results in Table 9 and Figure 9 show that during both seasons, plots treated with UAN fertilizer or 336 kg-N/ha from poultry manure produced significantly higher NO_3-N losses with subsurface drainage water when compared with plots treated with 168 kg-N/ha from poultry manure. The results given in Table 9 show that there were no significant differences in NO_3-N losses with surface runoff from the two poultry manure treatments. As expected, NO_3-N losses with surface runoff were not as high as NO_3-N losses through leaching. The average NO_3-N losses with surface runoff were less than 5 kg/ha.

The results presented in Table 9 and Figure 10 show that in 1998, PO_4-P concentrations were not significantly different between treatments. The results show that in 1999 plots treated with 336 kg-N/ha from poultry manure gave significantly higher concentrations of PO_4-P (greater than 0.02 mg/L) when compared with the other treatments. Figure 11 shows that the concentrations of PO_4-P in runoff were changing with each runoff event. In May 1998, plots treated with 168 kg-N/ha from poultry manure gave slightly higher PO_4-P concentration in surface runoff water in comparison with plots treated with 336 kg-N/ha from poultry manure. In June and August 1998, there were no differences in PO_4-P concentrations in runoff water from the two treatments. In July 1998, plots treated with 336 kg-N/ha from poultry manure produced significantly higher concentrations of PO_4-P when compared with plots treated with 168 kg-N/ha from poultry manure. The overall results show that in 1998, runoff water from plots treated with 336 kg-N/ha from poultry manure had higher average PO_4-P concentration when compared with plots treated with 168 kg-N/ha from poultry manure. Similar results were also obtained in 1999. The results in Table 10 also indicate that surface runoff had higher PO_4-P concentrations in comparison with subsurface drainage water. These results agree with previous studies (Baker and Laflen, 1982; Johnson et al., 1979; Sharpley et al., 1993) that produced higher PO_4-P concentrations in surface runoff water when compared with subsurface drainage water.

The data presented in Table 9 show that plots treated with 168 kg-N/ha from poultry manure gave the lowest average PO_4-P loss with drainage water followed by plots treated with UAN fertilizer and then plots treated with 336 kg-N/ha from poultry manure. Figure 12 shows that in April and May of 1998, plots treated with 336 kg-N/ha from poultry manure gave higher PO_4-P losses when compared with the other treatments. The average PO_4-P loss from plots treated with UAN fertilizer or 168 kg-N/ha from poultry manure were not significantly different from each other. In 1999, plots treated with 336 kg-N/ha from poultry manure gave higher losses of PO_4-P followed by plots treated with UAN fertilizer and then plots treated with 168 kg-N/ha from poultry manure. In August 1999, plots treated with 168 kg-N/ha from poultry manure produced significantly high PO_4-P loss in comparison with the other treatments.

Figure 13 shows that in 1998, plots treated with 336 kg-N/ha from poultry manure produced high PO_4-P loss with surface runoff in comparison with plots treated with 168 kg-N/ha from poultry manure. Figure 13 also shows that high PO_4-P losses occurred in June 1999 when compared with the other times. No PO_4-P losses were determined from sediments because runoff samples had little or no sediments. Overall, the results show that high annual PO_4-P losses occurred with surface runoff when compared with drainage water. These results are similar to results from previous studies by Baker and Laflen, (1982), Johnson et al., (1979) and Sharpley et al., (1993).

The results presented in Table 10 show that in June 1998, plots treated with 336 kg-N/ha from poultry manure produced significantly higher densities of fecal coliform bacteria in subsurface drainage water when compared with the other treatments. All samples from plots treated with UAN fertilizer or 168 kg-N/ha from poultry manure produced fecal coliform counts less than 200 cfu/100 ml. Similar results were also obtained in 1999 whereby plots treated with 336 kg-N/ha from poultry manure mostly produced fecal coliform counts greater than 200 cfu/100 ml in comparison with plots treated with UAN fertilizer or 168 kg-N/ha from poultry manure.

The results presented in Table 10 also show that in 1998 plots treated with 336 kg-N/ha from poultry manure gave higher counts of fecal streptococcus bacteria in subsurface drainage water when compared with the other treatments. Plots treated with either UAN fertilizer or 168 kg-N/ha from poultry manure produced fecal streptococcus counts less than 200 cfu/100 ml. The results also show that plots treated with poultry manure produced higher fecal streptococcus bacteria in 1999 when compared with 1998 indicating a build up of bacterial populations in the soil due to continuous use of manure (Smallbeck and Brommel, 1975; Faust, 1982). Plots treated with 168 kg-N/ha from UAN fertilizer gave fecal streptococcus counts less than 200 cfu/100 ml during most of the season, except in May and August 1999. Plots treated with 168 kg-N/ha from poultry manure also produced fecal streptococcus concentrations less than 200 cfu/100 ml during most part of the season except in July.

The results given in Table 10 show that in 1998, the concentrations of *E. coli* in drainage water from plots were very low. Brown et al., 1980; Kovacs and Tamasi, 1979 found similar results and attributed the low concentrations of *E. coil* to bacteria die-off due to sunlight and solar radiation. Other researchers (Edmonds, 1976; McCoy and Hagedorn, 1979; Gerber et al., 1975) attributed it to the fact that the surface soil and organic matter content in this layer could have acted as a biological filter and adsorption mechanism to the bacteria. In June 1998 plots treated with 336 kg-N/ha from poultry manure produced higher concentrations of *E. coli* when compared with other N treatments. Plots treated with either UAN fertilizer or 168 kg-N/ha from poultry manure produced low concentrations of *E. coli* throughout the two seasons. The results also show that in April 1999 (before manure application), plots treated with 336 kg-N/ha from poultry manure produced significantly higher *E. coli* when compared with the other treatments.

No runoff samples were analyzed for bacteria in 1998. High surface runoff in June 1999 resulted in high concentrations of fecal coliform bacteria in runoff water from plots treated with higher rate of poultry manure (Table 11). Higher application rate of poultry manure resulted in higher concentration of fecal coliform bacteria in runoff water in comparison with lower application rate.

The data in Table 11 also show that in May 1999, plots treated with 336 kg-N/ha from poultry manure gave higher counts of fecal streptococcus bacteria in surface runoff in comparison with plots treated with 168 kg-N/ha from poultry manure. In June 1999, there were no significant differences in densities of fecal streptococcus in runoff water from the two manure treatments. In general, the data show that fecal streptococcus counts in surface runoff water were higher than in subsurface drainage water indicating high pollution potential of surface water resources. These results agree with previous studies by McMurry et al. (1998) who reported high fecal streptococcus bacteria in runoff water than in subsurface drainage water. In general, the results indicate that application of poultry manure resulted in higher fecal streptococcus bacteria in surface runoff and subsurface drainage water in comparison with the application of UAN fertilizer.

The data presented in Table 11 show that in June 1999, plots treated with 336 kg-N/ha from poultry manure gave higher counts of *E. coli* bacteria in surface runoff water in comparison with plots treated with 168 kg-N/ha from poultry manure. These results show that intensive application of poultry manure could result in contamination of ground and surface water supplies with *E. coli* bacteria when compared with commercial fertilizer.

Background and Review of Literature

Historically, manure from domestic animals has been carefully conserved for its use as a crop fertilizer (Stewart, 1981). Then as supplies of inexpensive commercial fertilizers became plentiful, interest in the utilization of animal manure decreased to the point that manure was considered as a nuisance waste to be disposed of. It became increasingly difficult to convince farmers to buy and use manure as a fertilizer on their croplands because of the cheaper supply of commercial fertilizers. Now with the increasing costs, tightening supplies of fertilizers, and rapidly increasing costs of energy, animal manure is again perceived as an alternative nutrient source and valuable resource (Day, 1983; Fulhage, 1993). Cropland farmers have been willing once again to pay for animal manure (wastes) as well as to pay higher transportation costs to have these manure spread on their land. The relationship between animal waste management and environmental quality has been of interest to agricultural engineers and soil scientists for some time. Magette (1988) reported that up to the year 1966, the focus had been on defining a variety of problems involving waste management, but few environmental considerations were given attention. In 1971, when the American Society of Agricultural Engineers (ASAE) sponsored the first international symposium on livestock wastes, more attention was devoted to the impact on runoff water quality from areas treated with animal manure (Magette, 1988).

Magette (1988) also reported that when the Water Pollution Control Act Amendments of 1972 (P.L. 92-500) were passed by Congress, even more interest was drawn to animal waste management, but generally in terms of large feedlots since the emphasis in P.L. 92-500 was on point sources of pollution**.** Except where specific water quality problems were linked to animal manure application areas, the use of animal manure on cropland was generally accepted as an agricultural practice of little consequence environmentally. When Congress passed the Water Quality Act of 1987, which emphasizes controlling non point source pollutants, runoff and ground water quality from both manure treated pasture and cropland came under close scrutiny (Ritter, 1988)**.** The public awareness and concern for water quality has brought livestock operations under critical review as a possible source of polluting surface and ground water sources. However, poultry manure has not received the same level of attention from researchers as other agricultural wastes such as dairy manure and swine manure. Edwards and Daniel (1992) reported that a comprehensive review of the contribution of agricultural waste to non-point source pollution by Khaleel et al. (1980) contained no mention of the role of poultry manure.

Recent expansion in poultry production nationwide and its potential environmental impacts have placed poultry operations under greater public scrutiny than in the past. In recent years, poultry production in the United States has increased at a rate of 5% per year with an increase in per capita consumption acting as a driving force (Day 1981). Ningping and Edwards (1998) reported a national increase of broiler production by 20 to 30% in the next five years. More than six billion broiler chickens are raised in the US each year and produce more than nine million tons of poultry manure (Weaver, 1998). Poultry manure is a combination of the bedding material and manure (Wilson et al., 1998; Collins, 1996), or a mixture of poultry excreta, feathers, waste feed and bedding material (Evers, 1996; Weaver, 1998). Poultry manure, as a by-product of broiler and egg production is typically disposed on land in many states in the USA.

Agronomic benefits of applying poultry manure to forage and crops have been documented (Argerich et al., 1999; Day, 1983; Edwards and Daniel, 1992; Fulhage, 1993; Hunneycutt et al., 1988; Malik et al., 1999; Wood et al., 1996). However, the transport of poultry manure constituents off application sites and into downstream rivers and lakes is of increasing concern in regions having concentrated poultry production.

A number of studies have shown that if poultry manure is applied at excessive rates to cropland, instead of nourishing the crops, the nutrients (like N and P) in the manure become pollutants (Cooper et al., 1984; Fulhage, 1993b; Giddens and Barnett, 1980; Liebhardt et al., 1979). High nitrate (NO_3-N) concentrations in drinking water could possibly be detrimental to infants during the first six months of life and may develop methemoglobinemia (blue baby disease) if water containing higher concentrations of NO_3-N was used for mixing baby food. The U.S. Environmental Protection Agency (EPA) has set 10 mg/L N as the NO_3-N drinking water standard as a safeguard against methemoglobinemia from developing in infants. Municipal wells in some countries have been abandoned due to sustained concentrations in excess of 60 mg NO_3-N/L (Bjelm et al., 1980).

Potential surface and ground water contamination from poultry manure may occur from storage of poultry manure or from land application sites (Ritter, 1988). Previous research has demonstrated that applying poultry manure to range/pasture land areas affects runoff quality (Westerman et al., 1987; McLeod and Hegg, 1984; Edwards and Daniel, 1992). Ningping and Edwards (1998) reported that poultry manure might cause serious environmental problems if annual application rates exceed 8 Mg/ha. Bomke and Lavkulich (1975) found that heavy application of poultry manure greatly altered various soil chemical properties like increase in pH, available P, total N, NH_4^+ and in most cases NO_3-N, which threatened water quality. Giddens and Barnett (1980) reported that runoff from bare plots receiving higher application rates of poultry manure contained appreciable coliform bacteria; in some cases, the coliform content exceeded recreational and drinking water standards. Liebhardt et al. (1979) reported that at 179 tons/ha poultry manure application rate, resulted in NO_3-N concentrations in ground water ranging from 65 to 174 mg/L N at 3 m depth. On plots where no manure was applied, the NO_3-N concentrations in ground water ranged from 7 to 15 mg/L N. The authors also found that as the rate of poultry manure application increased so did the concentration of NO_3-N in the ground water. McLeod and Hegg (1984) investigated runoff quality impacts of pasture plots treated with municipal sludge, inorganic fertilizer, dairy manure, and poultry manure. Runoff from the plots was analyzed for total suspended solids (TSS), total Kjeldahl N (TKN), ammonium N, NO_3-N, total P (TP), and other parameters. The authors found that overall, runoff from plots treated with commercial fertilizer contained the highest concentrations of fertilizer constituents and NO_3-N concentration in runoff from the first rainfall exceeded drinking water standards. Runoff from plots treated with poultry manure had the overall next highest concentrations of fertilizer constituents.

Edwards and Daniel (1992) applied simulated rainfall to fescue plots 1 day following application of poultry manure. Runoff losses of all manure constituents increased with simulated rainfall intensity and increased approximately linearly with manure application rate. The authors also reported that when poultry manure was used to supply N requirements to crops, K and P were found to be in excess for bermudagrass, sweet clover, and many field crops. Even when poultry manure was applied at agronomic rates, P was known to accumulate in soils due to differences in proportions of N and P in litter and the proportions in which these nutrients were used by plants (Hileman, 1973). Poultry manure applied to fescue pastures in north Albama increased soil P levels by 530% to a depth of 45.7 cm compared to non-littered pastures (Kingery et al., 1993). Liebhart et al., 1979 attributed decreased corn yields to increased soil salinity following annual application rates of poultry manure of up to 224 Mg/ha. The authors also found that water-extractable K was much higher than either Ca or Mg, making K the prime suspect for increased salinity associated with poultry manure. Wood et al. (1996) reported that poultry manure applications increased concentrations of soil organic carbon, extractable P, K, Ca, Mg, copper (Cu), and zinc (Zn).

Robertson (1977) found that higher NO_3-N levels were commonly detected in areas with poultry operations when compared with areas that had no operations. Ritter and Chirnside (1984) found that 32% of the wells sampled in coastal Sussex County in an intensive ground water study had average NO_3-N concentrations above 10 mg/L. The highest NO_3-N concentrations occurred in areas with intensive broiler production or intensive crop production with excessively drained soils. The authors also found that in several areas, NO_3-N concentrations in the ground water decreased as the distance from poultry houses increased. Bachman (1984), in Delmarva Peninsula in western Maryland, reported higher NO_3-N concentrations at sites with urban and agricultural land uses and moderately drained soils. Water from wells near poultry houses had the highest median NO_3-N concentrations of 9.7 mg/L. Giddens and Barnett (1980) analyzed runoff from poultry manure treated plots for sediments and microbial content. Runoff from bare plots receiving higher application rates contained appreciable coliform bacteria; in some cases, the coliform content exceeded recreational and drinking water standards. The authors concluded that no water quality problems should result from application of "moderate" amounts of poultry manure unless "excessive" rainfall occurs.

Ritter (1988) pointed out that in applying poultry manure to cropland the key to reducing ground water contamination is nutrient management. The author suggested the following best management practices (BMPs) to emphasize nutrient management: applying only enough manure to be removed by the crop, manure nutrient analysis, soil test, calibration of manure spreader, timing of application, and liming. These BMPs were suggested because the amount of NO_3-N found in surface and ground water has been linked to the amount of N applied to the land (Hallberg, 1986). It is, therefore, important to determine the right amounts of poultry manure that can be applied to cropland in order to achieve the benefits of plant nutrients in the manure (for crop production) and at the same time maintain a clean environment. In Iowa, information on potential impacts of poultry manure application on surface and ground water quality is limited. Long-term research is, therefore, needed to understand the effect of poultry manure on water quality for Iowa soils. This is the first such study conducted in Iowa to evaluate the effects of poultry manure application on corn-soybean production system on water quality and crop yield.

Description of the Experimental Site and Experimental Treatments

Site: This study is being conducted at the Iowa State University's Agricultural Engineering and Agronomy Research Farm near Ames, Iowa. The experiment is being done on two levels: lysimeter and field plot experiments. The farm is on Nicollet loam soil formed in glacial till under the prairie vegetation with a maximum slope of 1%. The farm has been under no-till continuous corn production between 1984 and 1991. Since 1992, 10 plots were established and new farming systems introduced. The new farming systems include chisel plow tillage system, one crop rotation (corn-soybean rotation with corn grown on the northern part of the plot during the even numbered years and soybeans grown on the southern one-half of the plot. Eight experimental plots are instrumented with individual sumps and subsurface drainage metering and monitoring devices for collecting water samples for NO_3-N and pesticide analysis. Two plots are equipped with H-flume to collect surface runoff samples for water quality and erosion studies. Four plots have 10 sets of piezometers on both sides of tile drains to monitor the quality of shallow ground water below the subsurface drains. During the 1997 growing season, the plots were under three nitrogen management systems that included late N test (LNT), split nitrogen application, and single nitrogen application.

The lysimeter study was conducted using six field lysimeters. The lysimeters are arranged in two rows, spaced at 3.81 m between rows and between lysimeter boxes within rows. Each lysimeter is 2.28 m long x 1.5 m deep x 0.91 m wide. Full details of lysimeter installation are given by Blanchet (1996). During the 1997 growing season, the lysimeters were under one rate of commercial fertilizer and two swine manure application treatments.

Experimental Treatments: During the 1998 and 1999 growing seasons, in both lysimeter and plot experiments 168 kg N/ha from urea ammonium nitrate (UAN) commercial fertilizer, 168 kg N/ha from poultry manure and 336 kg N/ha from poultry manure were applied. The manure and fertilizer were incorporated/disked immediately after application to minimize losses through volatilization. Table 1 gives characteristics of the manure used during the two seasons. Treatments were randomly assigned to lysimeters and were replicated twice. A corn variety DK 580 was grown in all the lysimeters and plots during both seasons. In the plot experiment, the treatments were randomized and replicated three times for poultry manure and twice for commercial fertilizer. Corn was grown on the northern part of each plot (during even year) and soybeans (variety Kruger 2426) on the southern part. In 1999, corn was grown on the southern part of each plot (during old year) and soybeans on the northern part. Only 8 plots were used in the analysis of water quality due to lack of water monitoring devices in some plots. Data on daily tile flow from the plots were collected throughout the two years using an automatic flow recorder, while in the lysimeter experiment, amount of water was measured in the sumps. Water samples were taken from collection sumps once a week and immediately after individual rainfalls that caused tile drain to flow.

Treatments: In this study we observed the effects of the following three treatments of nitrogen application on water quality. Each treatment was replicated twice for lysimeters. In the field plots treatments were repeated twice and thrice for UAN fertilizer and poultry manure, respectively.

Treatment No. 1: Poultry manure was surface applied in early spring to give N application rates of 168 kg-N/ha. Immediately after the application of poultry manure, the soil surface was tilled using a field cultivator to mix the manure in the to 10 – 15 cm of the surface soil.

Treatment No. 2: Poultry manure was surface applied (and then mixed in the top 10 –15 cm of soil) to give N application rates of 336 kg-N/ha.

Treatment No.3: Commercial N fertilizer (urea ammonium nitrate, UAN) was surface applied to give N application rates of 168 kg-N/ha. Soil surface was then tilled to mix the fertilizer.

Planting and harvesting of corn and soybeans: The corn variety used for this experiment was Dekalb DK 580 and soybean variety was Kruger 2426. Only corn was grown in all lysimeters. In the field plots corn was grown on the northern one-half of the plot during even years (1998) and soybeans were grown on the southern one-half. Seeds were planted with a row-to-row spacing of 0.75 m and seed to seed distance of 0.2 m. Corn grain and soybean yields were determined at harvesting and were adjusted to 15.5% moisture content (wet basis). Grain samples were also analyzed for protein, fat, and carbohydrates content (adjusted to 15% moisture content) using near-infrared spectroscopy (NRS) to know if poultry manure has any effect on grain quality.

Drainage Water Samples for NO_3-N and PO_4-P Analyses: Subsurface drainage water samples were taken from subsurface drain and lysimeter sumps once a week or immediately after rainfall. Water samples were collected from each lysimeter and field plot in plastic test tubes of size 16*125 mm at the end of pumping without causing any cross contamination. Surface runoff samples were also collected whenever there was a runoff event. The water samples were stored at a temperature of 4^oC in walk-in-coolers immediately after collection. Water samples were later analyzed for NO_3-N and PO4-P in the National Soil Tilth Laboratory and Water Quality lab of the Agricultural and Biosystems Engineering Department at Iowa State University, Ames, Iowa, respectively. Samples were analyzed according to EPA Method 353.2 (EPA, 1993). The NO_3-N concentrations in the drainage water were determined using the automated cadmium reduction method with Technicon automated analyzer. The PO_4-P concentrations in the drainage water were determined using Phosphomolybdate Ascorbic Acid method (Arnold et al., 1992).

Sample Collection and Enumeration for Bacteria: The method of sample collection for enumeration of bacteria should be done aseptically. Water samples were taken from the subsurface drain and lysimeter sumps once a week and immediately after rainfall. Lysimeter sumps had to be pumped empty and volume measured every week. Subsurface drainage water samples were collected in sterile plastic bags at the end of pumping from lysimeter sumps in order to eliminate any cross contamination between samples and were stored immediately at a temperature of 4^oC. Subsurface drain water samples from field plots were collected weekly on a grab basis as drains run continuously. Water samples were analyzed for fecal coliform, *E. coli* and fecal streptococcus bacteria within 24 hr of their collection.

The sampling procedures, including collection, storage, and analysis for the determination of fecal coliform, *E.coli* and fecal streptococcus were done according to Standard Methods for the Examination of Water and Wastewater (Anorld et al., 1992). Determination of densities of fecal coliform bacteria in the water samples was done using Membrane Filter (MF) technique (Anorld et al., 1992). The MF technique is highly reproducible and can be used to test relatively large volumes of samples, and yields results rapidly. Sample volumes of 100, 50, and 10 ml were filtered through 0.45 μm sterile membranes. These filters were transferred to M-FC medium (Difco Laboratories, 1984) in a petri dish, avoiding air bubbles beneath the membrane.

The fecal coliform culture plates were inverted and incubated for 24 hr at 44.5^oC in a constant temperature incubator. The colonies were counted after 24 hr of incubation. The colonies produced by fecal coliform and *E.coli* bacteria were blue in color. The density of the bacteria was recorded in terms of colony forming units per mL (cfu/100ml). The colonies were counted by multiplying the total number of colonies per plate by the reciprocal of their dilution.

If the total number of colonies exceeded 200 per membrane, then they were reported as too numerous to count (tntc). The data obtained from replications of a treatment were averaged. Determination of E. coli was done using the same procedure described for fecal coliform.

The density of fecal streptococcus bacteria in drainage water was determined by using the MF technique. Sample volumes of 100, 50, 10 ml were filtered through 0.45 μm sterile membranes. These filters were then transferred to M-enterococcus media (Difco Laboratories, 1984) in a petri dish, avoiding air bubbles beneath the membrane. These culture plates were inverted and incubated for 48 hr at 37^{o}C in an incubator. The colonies were counted after 48 hr of incubation. The colonies produced by fecal streptococcus bacteria were light or dark red in color. The density of fecal streptococcus was recorded in terms of cfu/100ml. If the total number of colonies exceeded 200 per membrane, then they were reported as too numerous to count. The data obtained from replications of a treatment were averaged.

B. DIFFICULTIES ENCOUNTERED AND IMPROVEMENTS IN METHODS

In fact, everything went very well in 1999, the second year of this study. Manure was applied on time in both years. Instrumentation functioned very well. The weather was favorable for crop production as is reflected by higher corn yields from both lysimeters and field plots. The only difficulty we encountered was on the installation of a sump for one of the plots receiving neither poultry manure nor UAN fertilizer. This sump has now been installed. Therefore, we will be able to collect water samples for NO_3-N and PO_4-P analyses from this newly included plot that receives neither UAN fertilizer nor poultry manure.

C. PLANS FOR THE COMING YEAR

We will follow the same procedures and experimental treatments as were in the 1998 and 1999 cropping seasons. No change is proposed in experimental methods and analytical procedures. All the methods and procedures are given in the previous section.

D. SCHOLARLY PUBLICATIONS

Results from the first year of the experiment were summarized in a paper and presented at the Mid-Central Region Conference of the American Society of Agricultural Engineers in St. Joseph, Missouri in April 1999. The 1998 and 1999 results will also be summarized in a paper format and be presented at the Mid-Central region Conference of the American Society of Agricultural Engineers in St. Joseph, Missouri in April 2000. We have also submitted a paper proposal to present the results of this study at the 2000 American Society of Agricultural Engineers Annual International Meeting in Milwaukee, Wisconsin in July 2000. Following is the citation of the paper presented at the ASAE Mid-Central Region Conference. Chinkuyu, A.J., R.S. Kanwar, J.C. Lorimor, and H. Xin. 1999. Use of poultry manure for crop production and its impacts on water quality. Paper presented at the 1999 Mid Central ASAE Meeting at St. Joseph, MO, April 30 – May 1, 1999. MC 99-140.

E. POPULAR PRESS COVERAGE

We have not sent any popular press release to this day. As soon as we complete the third year of this study, we plan to send a press release in December 2000 to highlight the results from this poultry manure project.

F. EDUCATION AND OUTREACH

In 1999, results were presented at the Agronomy Field day, which was attended by 600 to 700 people representing farmers, crop consultants, seed and chemical companies, and state and federal agencies. Field tours have also been conducted for students taking water resources and water quality classes. Several visiting professors/scientists from other countries visited this site. In 1998, 22 people of the World Bank visited this site. Also, we presented results of this study at the annual meetings of the Iowa Egg council.

G. COOPERATIVE EFFORTS

This research is being conducted by an interdisciplinary research team of engineers and scientists (from the Iowa Agriculture and Home Economics Experiment Station and the Cooperative Extension service). Dr. Ramesh Kanwar is an Agricultural Engineer and hydrologist from Iowa State University who brings to the project an experience in the area of surface and groundwater hydrology (quality and quantity). Dr. Kanwar was responsible for implementing the manure treatments, collect soil and water sample for water quality analysis, and interpreted results from this experiment. Drs. Jeff Lorimor and Hongwei Xin are Agricultural Engineers from Iowa State University with research and extension appointments. Dr. Lorimor was responsible for arranging poultry manure from the Iowa poultry producers and helped in analyzing the nutrient contents of the poultry manure so that right amount of N can be applied to lysimeters and plots. Dr Xin helped in determining the ammonia losses (if any) from lysimeters and plots so that N mass balance could be accurately determined. Dr. Jim Baker, Professor of Agricultural and Biosystems Engineering is a cooperator on this project and assured the quality of laboratory analyses for NO_3-N, PO_4-P and bacteria.

This project study is being conducted in cooperation with Iowa Egg Council and one poultry producer in Iowa (Farm Egg Products, Humboldt, IA). This producer owns very large operation having 1 to 1.25 million poultry layers housed in 10 to 12 different houses. This producer has gladly supplied solid poultry manure, which contains 20 to 65% moisture content. The members of Iowa Egg Council have been very helpful in making suggestions for improvements in data collection procedures for this project.

Table 1. Characteristics of the poultry manure applied during the 1998 and 1999 growing seasons.

Characteristics	Nitrogen Treatment and Year: 168 kg-N/ha Poultry manure		336 kg-N/ha Poultry manure	
	1998	1999	1998	1999
Plot experiment:				
Average amount applied, kg per plot	2716	1432	5889	2824
Average application rate, Mg/ha	20.27	10.50	40.00	18.91
Total Kjedhal nitrogen (TKN), %N	1.49	3.04	1.51	3.11
Ammonia (NH_3), %N	0.52	0.77	0.52	0.77
Total Phosphorus, % P	1.00	0.44	0.94	0.46
Potassium, %K	1.84	2.09	1.84	2.09
Moisture content, %	45.03	48.00	45.03	48.00
Lysimeter experiment:				
Average amount applied, kg per lysimeter	4.18	1.83	8.36	3.66
Average application rate, Mg/ha	19.90	8.71	39.81	17.43
Total Kjedhal nitrogen (TKN), %N	1.27	2.90	1.27	2.90
Ammonia (NH_3), %N	0.52	0.77	0.52	0.77
Total Phosphorus, % P	1.00	0.44	0.94	0.46
Potassium, %K	1.84	2.09	1.84	2.09
Moisture content, %	45.03	48.00	45.03	48.00

Assumed 5% N lost during application.

Table 2. Corn yields, quality of corn grains and concentration of N in corn stalks from lysimeter experiment under different N treatments during the 1998 and 1999 growing seasons.

	Year	Nitrogen Treatments and Application Rates: 168 kg-N/ha UAN	168 kg-N/ha Poultry Manure	336 kg-N/ha Poultry Manure
Yields, Mg/ha	1998	3.80	5.46	6.18
	1999	7.45	9.10	9.53
	Average	5.62	7.28	7.85
Stalk N, ppm	1998	19.00	9.00	100.00
	1999	5.00	6.00	13.00
	Average	12.00	8.00	57.00
Protein, %	1998	9.10	7.80	8.60
	1999	6.60	5.60	7.00
	Average	7.90	6.70	7.80
Starch, %	1998	61.10	61.70	61.30
	1999	62.30	63.00	62.00
	Average	61.70	62.40	61.70
Oil, %	1998	2.90	3.20	3.10
	1999	3.70	3.90	3.70
	Average	3.30	3.60	3.40

Table 3. Average NO_3-N concentrations in the soil profile in lysimeters before planting and after harvesting during the study period.

Date	Depth	Nitrogen Treatment 168 kg-N/ha UAN	168 kg-N/ha Poultry manure	336 kg-N/ha Poultry manure
	cm	--------------- NO_3-N concentration, ppm		-------------
Before planting 5/12/98	0-30	8.31	15.73	12.30
	30-45	4.34	5.54	6.13
	45-61	4.69	5.26	6.06
After harvesting 10/5/98	0-30	5.55	8.10	14.50
	30-45	4.60	3.05	5.64
	45-61	2.35	1.75	4.65
Before planting 5/12/99	0-15	3.80	2.55	1.85
	15-30	3.15	3.35	2.85
	30-45	2.85	3.58	2.55
	45-61	3.50	3.50	3.15
	61-91	2.25	2.20	3.10

Table 4. Annual subsurface drainage flow, NO_3-N and PO_4-P concentrations (mg/l) and losses (kg/ha) with subsurface drainage water from lysimeters under different N treatments.

Year	Nitrogen Treatment 168 kg-N/ha UAN	168 kg-N/ha Poultry manure	336 kg-N/ha Poultry manure
		Drainage flow (cm)	
1998	27.6	20.4	23.3
1999	32.7	27.4	33.3
Average	30.2	23.9	28.3
		NO_3-N concentration in drain water	
1998	14.7	9.6	13.2
1999	8.2	9.2	14.7
Average	11.5	9.4	14.0
		NO_3-N loss with drain water	
1998	40.6	19.6	30.8
1999	26.8	25.2	49.0
Average	33.7	22.4	39.9
		PO_4-P concentration in drain water	
1998	0.110	0.020	0.016
1999	0.091	0.052	0.081
Average	0.101	0.036	0.049
		PO_4-P loss with drain water	
1998	0.272	0.036	0.035
1999	0.096	0.060	0.177
Average	0.184	0.048	0.106

Table 5. Weekly densities of fecal coliform, fecal streptococcus, and E. coli bacteria in drainage water from lysimeters under different N treatments.

	Nitrogen Treatment and Type of Bacteria								
	Fecal coliform			**Fecal streptococcus**			**E. coli**		
Date	**168 UAN**	**168 PM**	**336 PM**	**168 UAN**	**168 PM**	**336 PM**	**168 UAN**	**168 PM**	**336 PM**
1998	------------------------------------ Bacteria counts, cfu/100 ml ------------------------								
5/20/98	23	0	2	0	0	0	1	0	10
5/25/98	22	33	10	58	tntc	tntc	0	30	44
6/2/98	30	0	0	13	12	tntc	19	0	17
6/9/98	100	99	tntc[φ]	0	0	0	54	tntc	tntc
6/12/98	38	11	140	23	370	tntc	tntc	tntc	tntc
6/16/98	159	55	tntc	44	tntc	tntc	21	97	tntc
6/22/98	0	53	tntc	30	65	257	0	0	0
7/7/98	0	0	299	37	39	tntc	0	0	0
1999									
4/27/99	100	tntc	tntc	55	tntc	237	tntc	tntc	tntc
5/4/99	147	10	0	14	25	35	1	2	4
5/11/99	11	0	7	7	19	35	0	20	5
5/12/99	190	tntc	tntc	tntc	tntc	tntc	125	52	143
5/19/99	-	-	-	-	-	-	-	-	-
5/25/99	3	20	2	151	tntc	35	0	46	0
6/1/99	6	3	3	27	13	12	6	4	3
6/8/99	0	0	0	94	25	7	64	4	0
6/15/99	181	46	10	137	243	tntc	125	40	19
6/22/99	16	8	0	104	27	19	10	13	0
6/29/99	19	22	20	121	41	16	40	22	10
7/6/99	1	13	1	155	173	20	1	13	3
7/13/99	214	tntc	tntc	132	237	310	0	1	1
7/20/99	tntc	tntc	tntc	tntc	tntc	tntc	0	64	0
8/18/99	-	-	-	-	-	-	-	-	-

168 UAN: 168 kg-N/ha from UAN, 168 PM: 168 kg-N/ha from poultry manure, 336 PM: 336 kg-N/ha from poultry manure.

[φ] tntc: too numerous to count when bacteria colonies exceed 200 per membrane

Table 6. Corn and soybean yields at 15.5% moisture content from plots under different N treatments in 1998 and 1999.

Year	Iowa average	Nitrogen Treatments and Application Dates 168 kg-N/ha UAN	168 kg-N/ha Poultry Manure	336 kg-N/ha Poultry Manure	Check plot (O-N/ha)
	----------	----------	Mg/ha	----------	----------
Corn from plots:					
1998	9.22	8.41	9.45	9.14	4.09
1999	9.48	9.13	10.48	10.64	5.46
Average	9.35	8.77	9.96	9.89	4.77
Soybean from plots:					
1998	3.27	4.08	3.97	4.30	3.57
1999	3.07	3.65	3.93	3.97	3.53
Average	3.17	3.87	3.95	4.14	3.55

Table 7. Concentration of N in corn stalks and quality of corn grains and soybeans from plots under different N treatments.

Nitrogen Treatment	Type of Crop Corn Stalk N	Protein	Starch	Oil	Density	Soybean Protein	Oil	Fiber
	ppm	----------	----------	----------	%	----------	----------	----------
					1998			
168 UAN	186	7.0	61.7	3.3	1.25	35.7	18.1	5.0
168 PM	763	6.7	61.7	3.5	1.25	35.7	18.1	5.0
336 PM	3299	7.3	61.4	3.5	1.27	35.4	18.0	4.9
Check	38	5.6	62.0	3.5	1.22	35.8	18.8	4.9
					1999			
168 UAN	784	7.1	61.7	3.7	1.26	36.1	16.3	5.4
168 PM	2686	7.3	61.3	3.9	1.28	36.0	16.4	5.3
336 PM	3895	7.6	61.3	3.8	1.28	36.0	16.3	5.4
Check	15	6.3	62.4	3.8	1.26	36.3	16.4	5.3

168 UAN: 168 kg-N/ha from UAN, 168 PM: 168 kg-N/ha from poultry manure, 336 PM: 336 kg-N/ha from poultry manure

Table 8. Average NO_3-N concentration in the soil profile in plots before planting and after harvesting during the study period.

		Nitrogen Treatment			
Date	**Depth**	**Check plot**	**168 kg-N/ha UAN**	**168 kg-N/ha Poultry manure**	**336 kg-N/ha Poultry manure**
Before planting	cm	---------------------- NO_3-N concentration, ppm ------------			
5/12/98	0-15	-	-	-	-
	15-30	-	-	-	-
	30-45	-	-	-	-
	45-61	-	-	-	-
After harvesting	0-15	7.90	10.00	11.40	16.93
11/5/98	15-30	4.90	9.18	6.37	18.50
	30-61	1.10	3.25	3.67	18.53
	61-91	-	2.25	2.60	5.80
	91-120	-	1.25	1.10	1.50
Before planting	0-15	16.00	35.78	10.77	12.73
5/12/99	15-30	5.50	15.75	4.87	5.37
	30-61	4.20	9.48	5.17	4.83
	61-91	4.20	4.95	4.20	3.30
	91-120	2.30	3.03	2.93	2.53

Table 9. Annual subsurface drainage flow, NO_3-N and PO_4-P concentrations (mg/l) and losses (kg/ha) with subsurface drainage and surface runoff water from plots under different N treatments.

Year	Rain	Subsurface drainage water Nitrogen treatment 168 kg-N/ha UAN	 168 kg-N/ha Poultry manure	 336 kg-N/ha Poultry manure	Surface runoff water Nitrogen treatment 168 kg-N/ha Poultry manure	 336 kg-N/ha Poultry manure
Plots:	cm			Drainage flow (cm)		
1998	88.5	25.0	17.5	19.1	2.5	2.9
1999	86.4	18.9	12.4	15.0	2.7	1.8
Average		22.0	15.0	17.1	2.6	2.3
				NO_3-N concentration in drain water		
1998		19.9	17.0	25.0	13.8	14.4
1999		21.4	20.9	31.2	4.1	5.6
Average		20.7	19.0	28.1	9.0	10.0
				NO_3-N loss with drain water		
1998		49.8	29.8	47.8	3.6	4.2
1999		40.5	25.9	46.8	0.9	0.9
Average		45.1	27.8	47.3	2.3	2.6
Average						
Plots:				PO_4-P concentration in drain water		
1998		0.016	0.026	0.026	0.130	0.146
1999		0.026	0.015	0.070	0.090	0.099
Average		0.021	0.021	0.048	0.110	0.123
				PO_4-P loss with drain water		
1998		0.033	0.035	0.083	0.330	0.419
1999		0.033	0.016	0.041	0.244	0.178
Average		0.033	0.026	0.062	0.287	0.299

Table 10. Weekly densities of fecal coliform, fecal streptococcus, and E. coli bacteria in drainage water from plots under different N treatments.

	Nitrogen Treatment and type of Bacteria								
	Fecal coliform			Fecal streptococcus			E. coli		
Date	168 UAN	168 PM	336 PM	168 UAN	168 PM	336 PM	168 UAN	168 PM	336 PM
1998	------------------------------------ Bacteria counts, cfu/100 ml -------------------------								
6/2/98	9	0	54	14	10	26	0	20	52
6/9/98	17	16	tntc[φ]	0	0	0	10	47	tntc
6/12/98	9	7	tntc	64	69	tntc	10	23	44
6/16/98	20	10	0	57	119	217	-	-	-
1999									
4/27/99	tntc	46	tntc	5	9	13	22	32	tntc
5/4/99	1	1	1	5	2	12	0	0	1
5/11/99	1	0	10	0	0	30	0	1	54
5/12/99	tntc	tntc	tntc	tntc	tntc	tntc	125	273	345
5/19/99	5	10	45	22	76	62	1	25	12
5/25/99	7	8	253	7	5	14	3	6	26
6/1/99	3	2	tntc	157	1	53	0	19	19
6/8/99	0	0	411	6	23	tntc	0	0	tntc
6/15/99	0	3	66	25	19	tntc	14	5	43
6/22/99	10	8	43	10	21	25	0	0	1
6/29/99	7	1	1	2	2	10	0	0	0
7/6/99	9	48	13	35	259	165	1	9	8
7/13/99	7	1	tntc	5	0	10	0	0	0
7/20/99	-	tntc	tntc	0	tntc	tntc	-	8	95
8/18/99	200	200	389	332	168	tntc	7	33	53

168 UAN: 168 kg-N/ha from UAN, 168 PM: 168 kg-N/ha from poultry manure, 336 PM: 336 kg-N/ha from poultry manure.

[φ] tntc: too numerous to count when bacteria colonies exceed 200 per membrane.

Table 11. Weekly densities of fecal coliform, fecal streptococcus, and E. coli bacteria in runoff water from plots under different manure application rates.

	Nitrogen Treatment and Type of Bacteria					
	Fecal coliform		Fecal streptococcus		E. coli	
Date	168 PM	336 PM	168 PM	336 PM	168 PM	336 PM
1999	--------------------------- Bacteria counts, cfu/100 ml --------------------------					
5/12/99	0	85	tntc	0	10	0
6/9/99	0	tntc	tntc	tntc	57	231
6/23/99	110	tntc	75	tntc	65	102
8/18/99	10	50	41	65	8	36

168 UAN: 168 kg-N/ha from UAN, 168 PM: 168 kg-N/ha from poultry manure, 336 PM: 336 kg-N/ha from poultry manure.

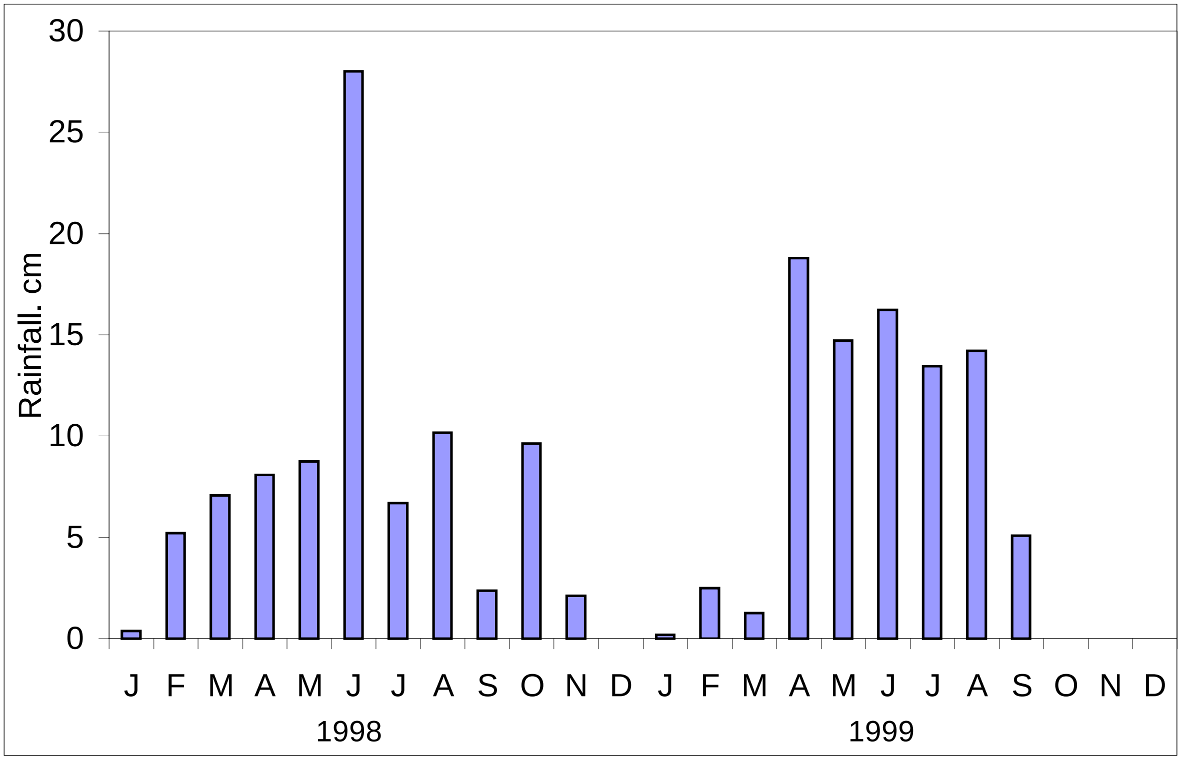

Figure 1. Amount of rainfall at the experiment site during the 1998 and 1999 growing seasons.

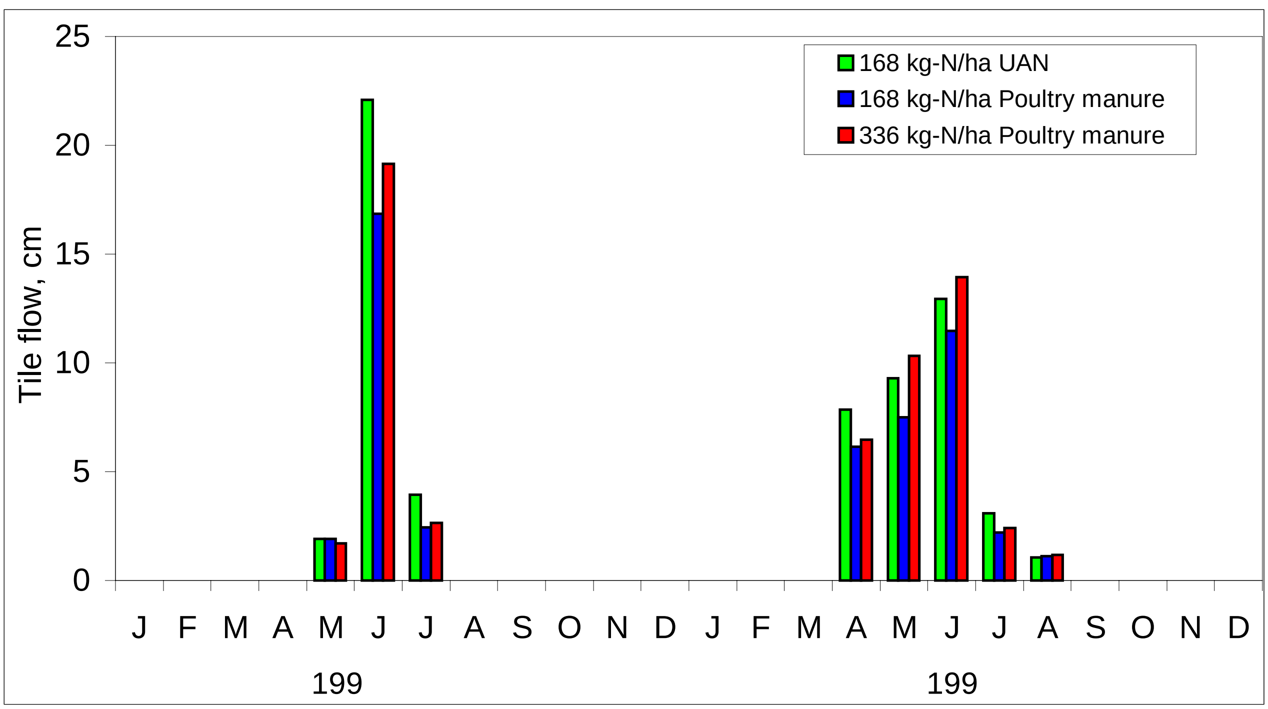

Figure 2. Amount of subsurface drainage water from lysimeters under different N treatments during the 1998 and 1999 growing seasons.

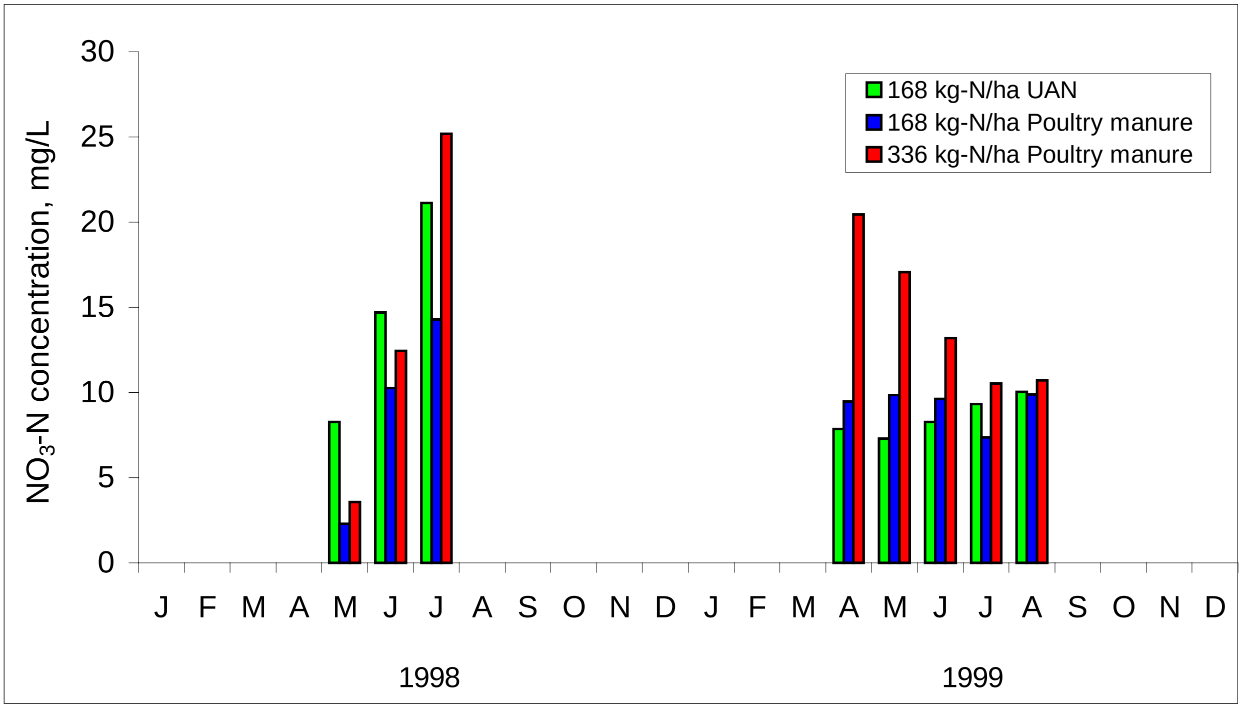

Figure 3. Average monthly NO_3-N concentration in subsurface drainage water from lysimeters during the 1998 and 1999 growing seasons.

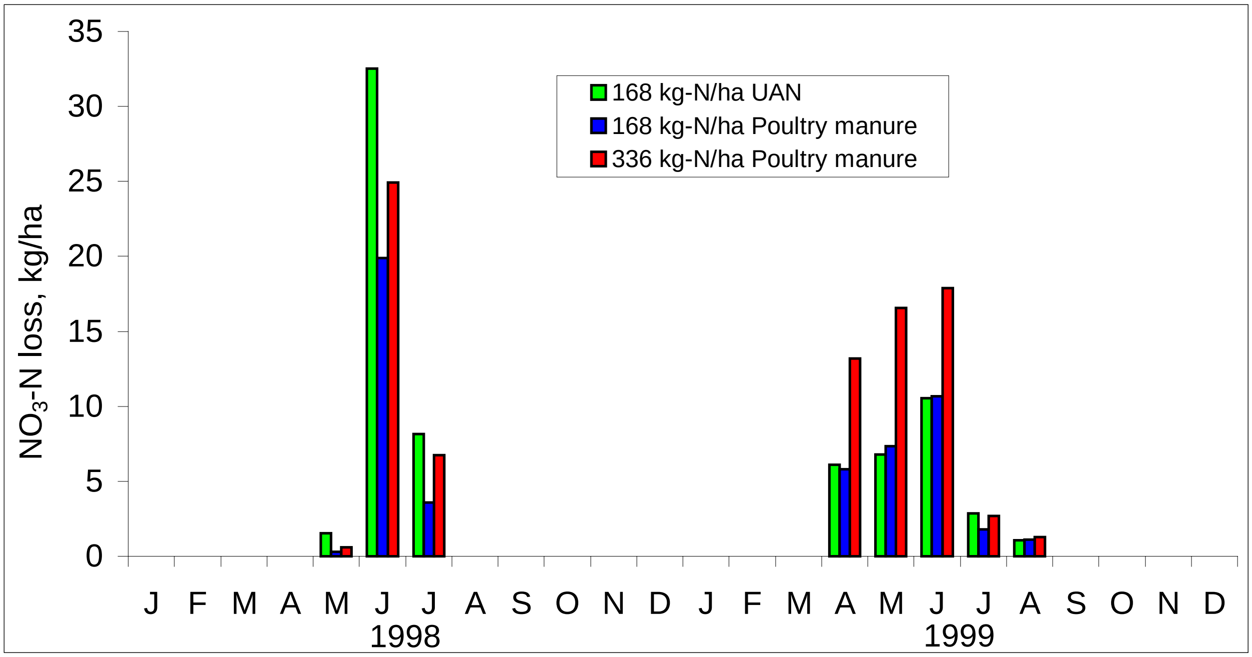

Figure 4. Average monthly NO_3-N loss with subsurface drainage water from lysimeters during the 1998 and 1999 growing seasons.

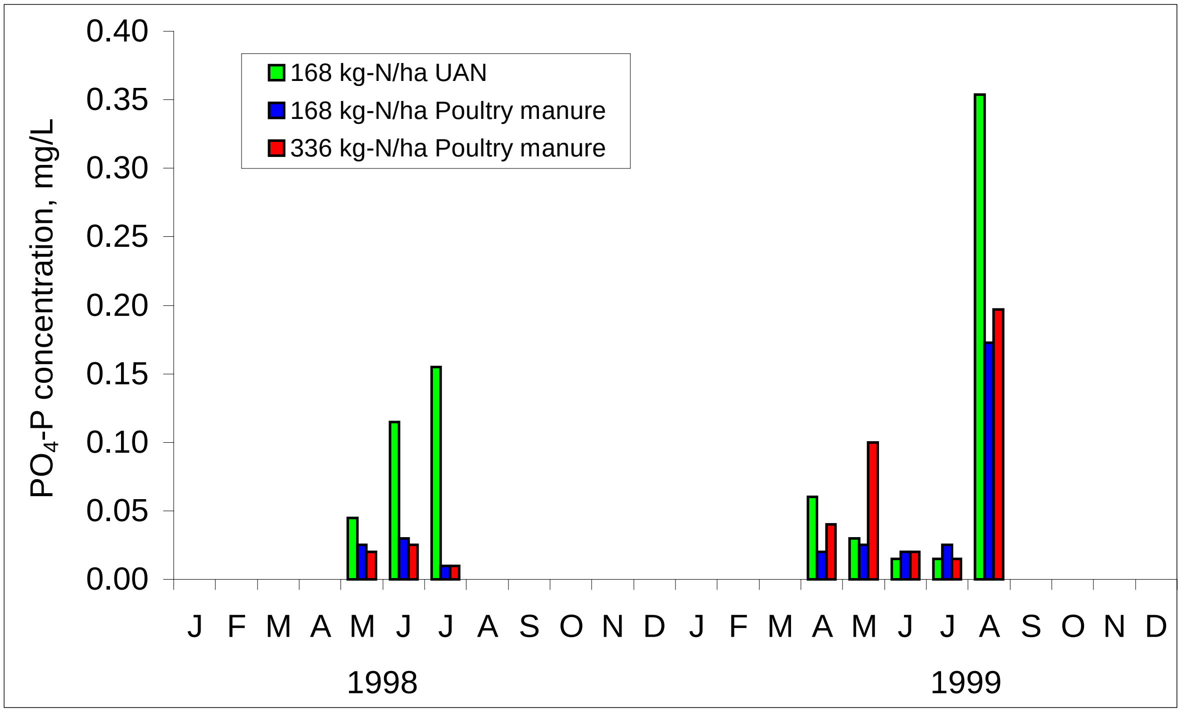

Figure 5. Average monthly PO_4-P concentration in subsurface drainage water from lysimeters during the 1998 and 1999 growing seasons.

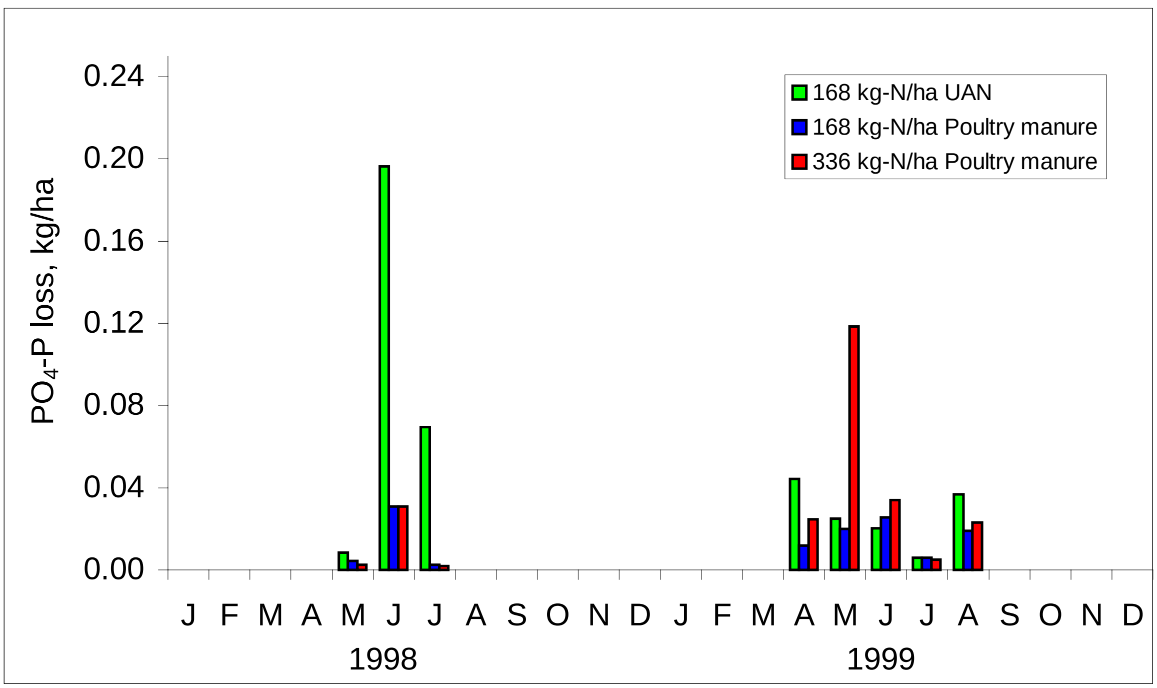

Figure 6. Average monthly PO_4-P loss with subsurface drainage water from lysimeters during the 1998 and 1999 growing seasons.

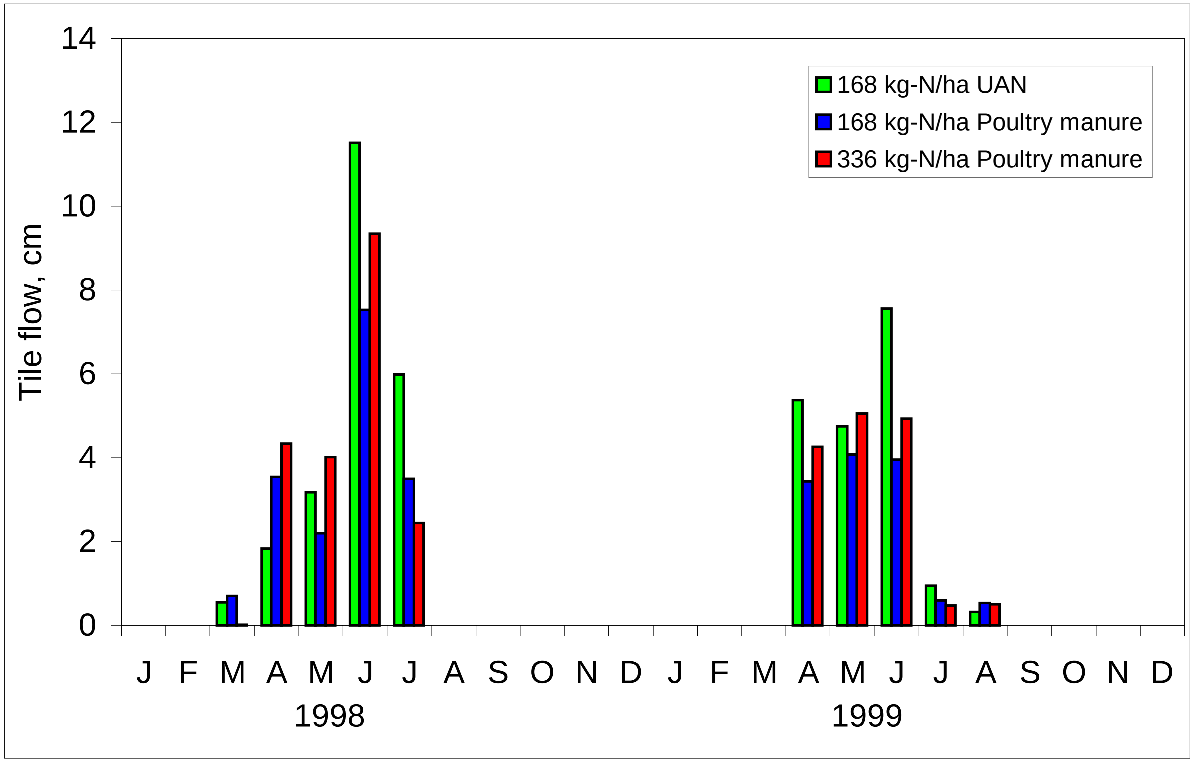

Figure 7. Amount of subsurface drainage water from field plots under different N treatments during the 1998 and 1999 growing seasons.

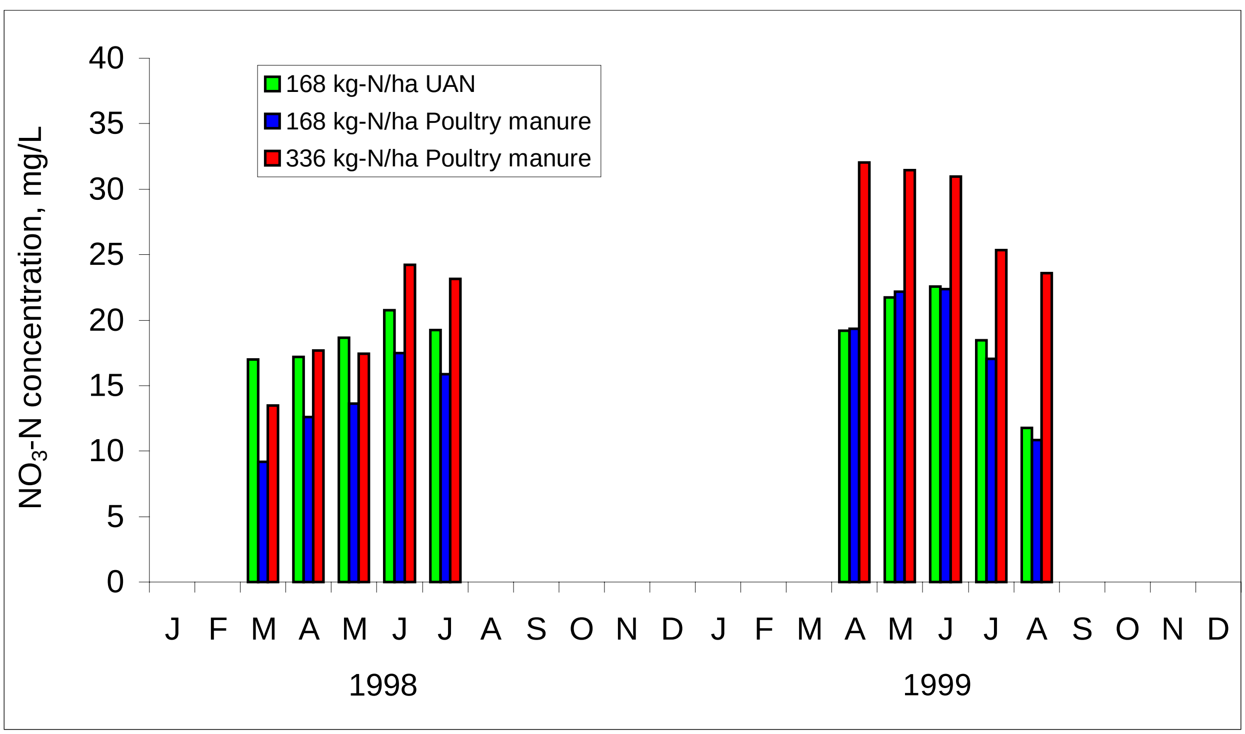

Figure 8. Average monthly NO_3-N concentration in subsurface drainage water from plots during the 1998 and 1999 growing seasons.

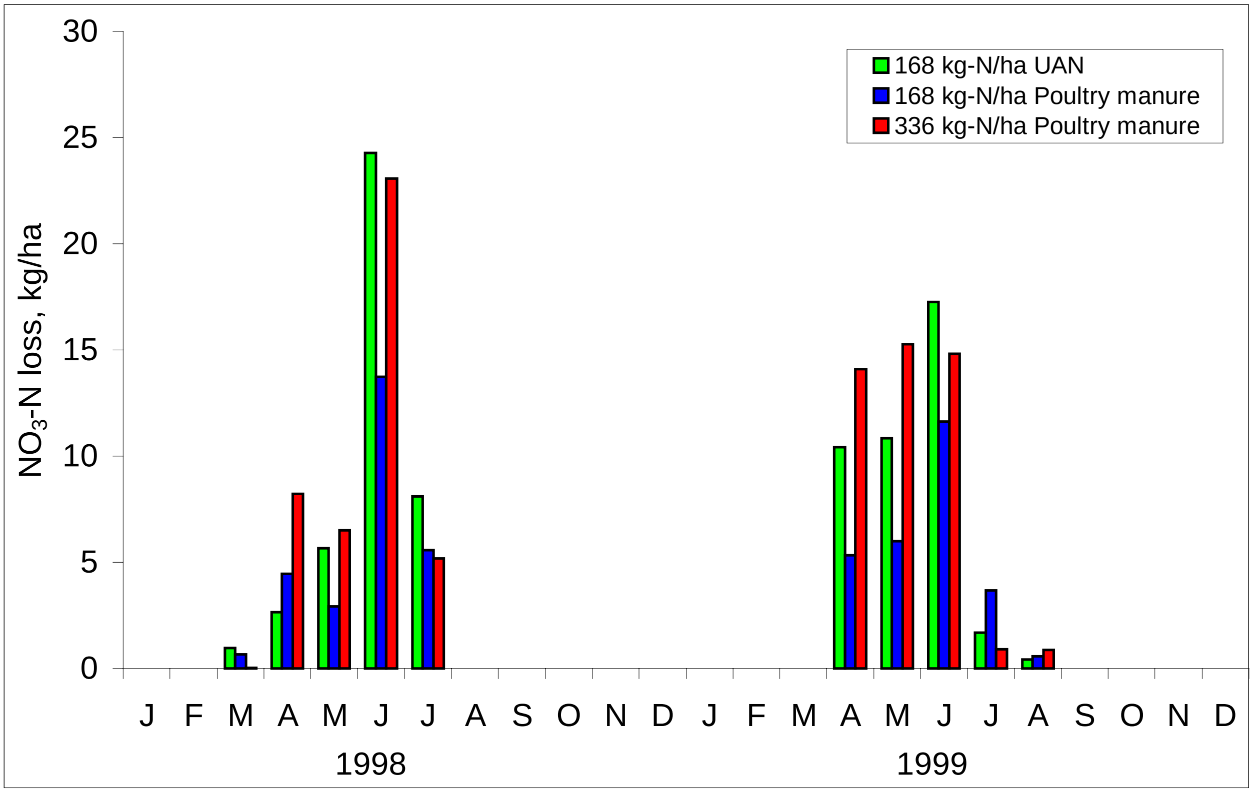

Figure 9. Average monthly NO_3-N loss with subsurface drainage water from plots during the 1998 and 1999 growing seasons.

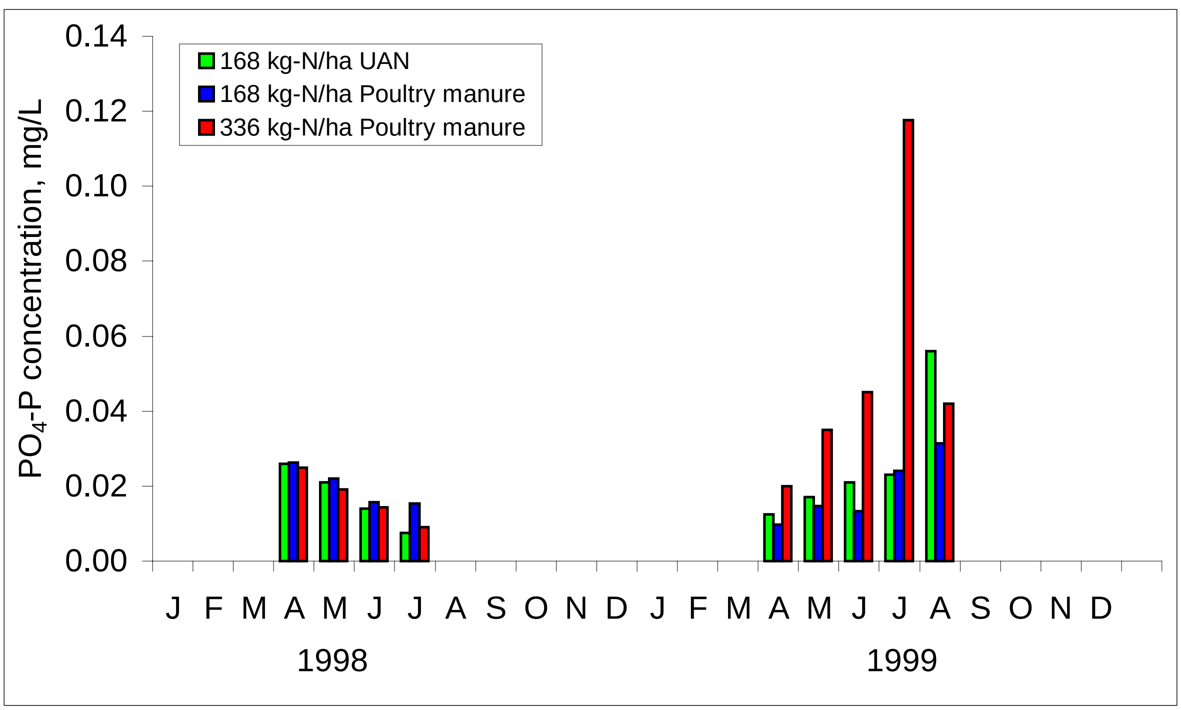

Figure 10. Average monthly PO_4-P concentration in subsurface drainage water from field plots during the 1998 and 1999 growing seasons.

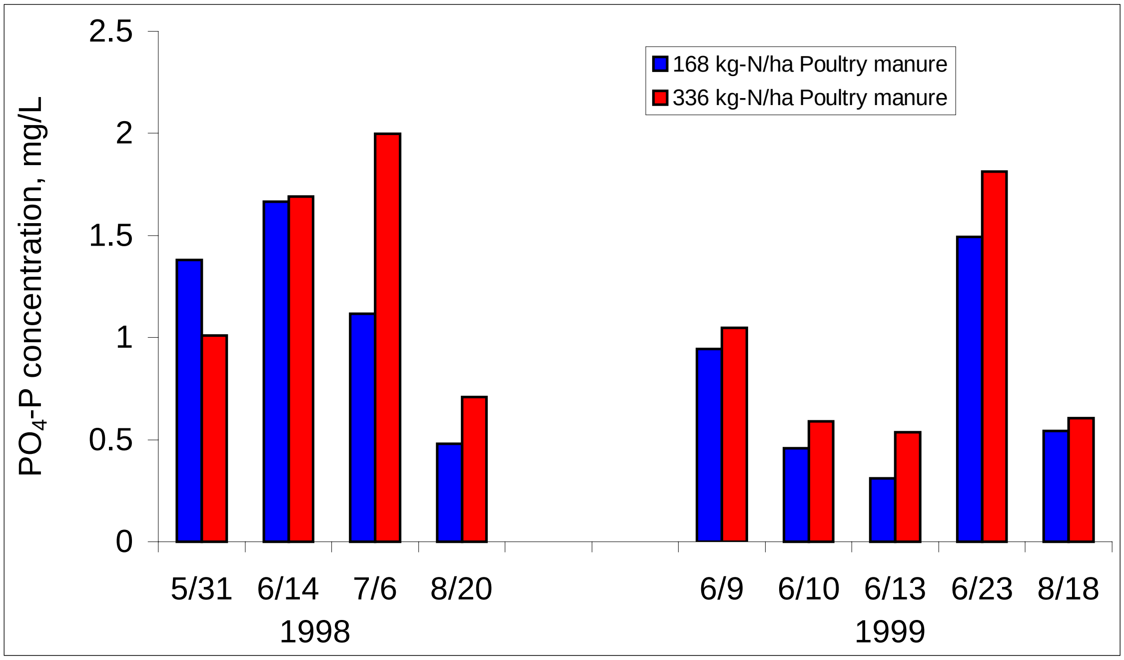

Figure 11. PO_4-P concentration in surface runoff water from plots under different amounts of poultry manure during the 1998 and 1999 growing seasons.

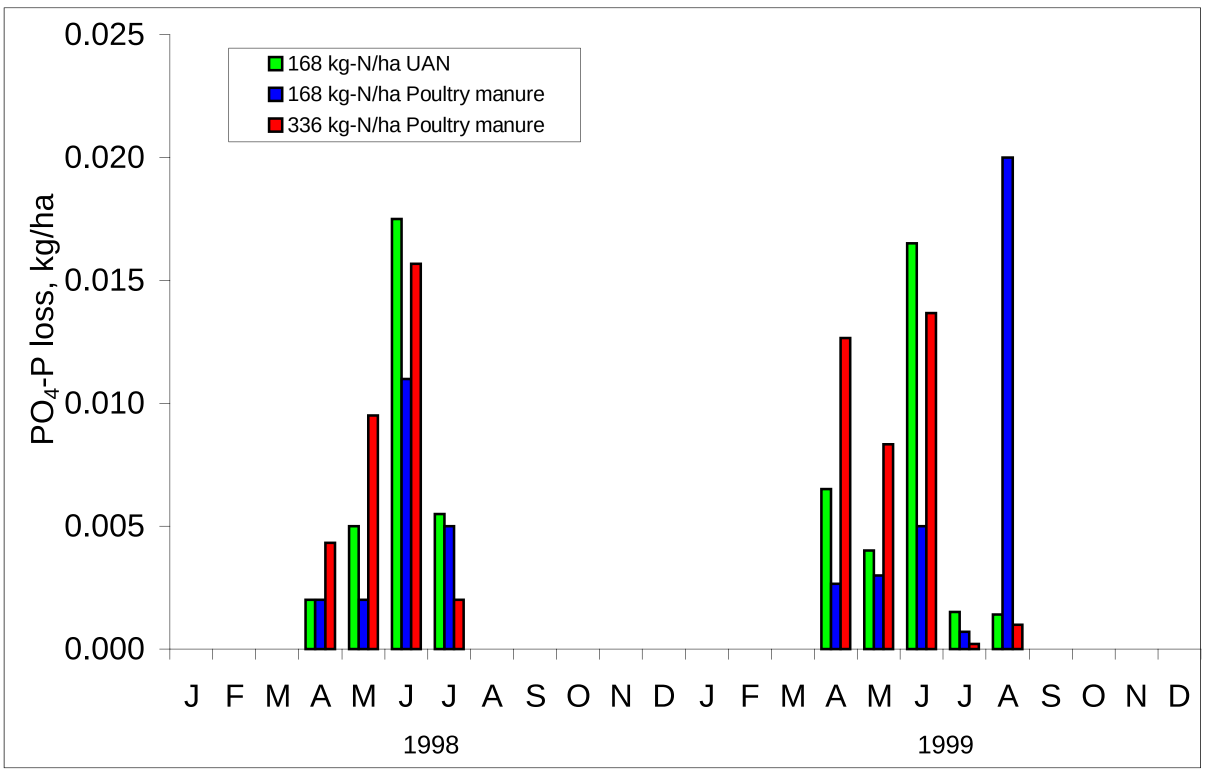

Figure 12. Average monthly PO_4-P loss with subsurface drainage water from plots during the 1998 and 1999 growing seasons.

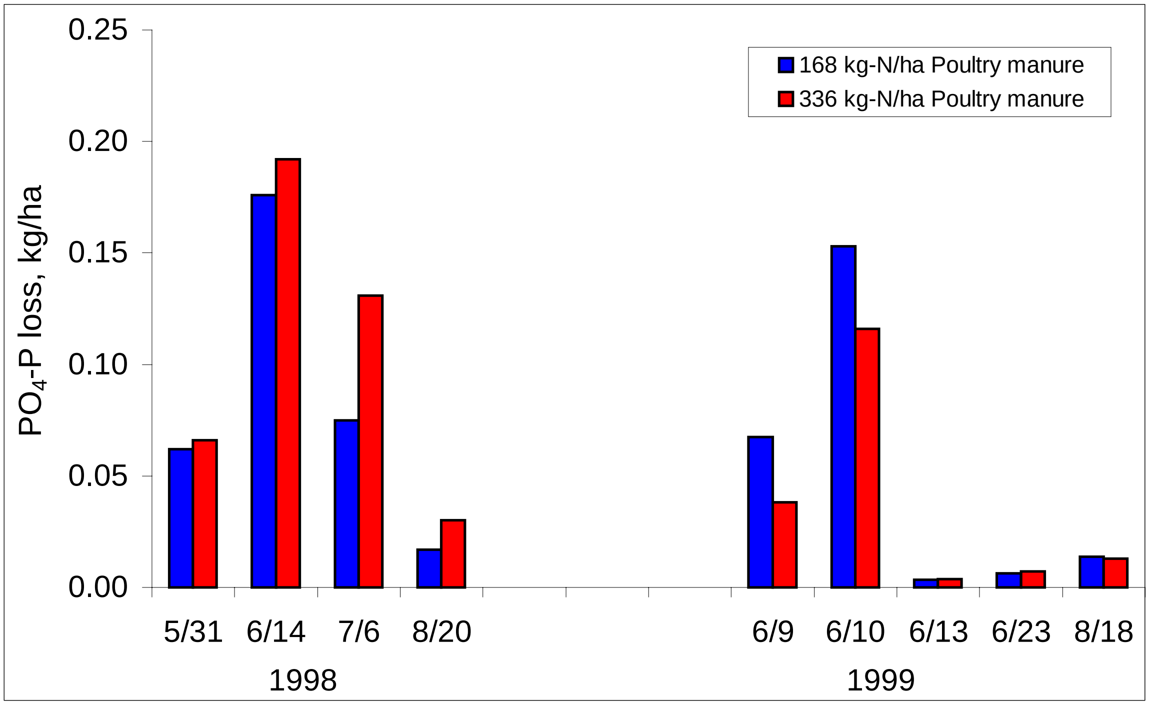

Figure 13. PO_4-P loss with surface runoff from plots under different amounts of poultry manure during the 1998 and 1999 growing seasons.

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H. **Budget Requested for FY 2001**

Category	**Leopold Center**	**In kind Contributions**	**Additional Grants**	**Total**
Salary and Wages	---------------------------------------	$	---------------------------------------	
Professional	-	25,000	-	25,000
Graduate Students	15,200	-	2,000*	17,200
Technical Support Hourly	2,500	-	-	2,500
Benefits	800	-	-	800
Travel	800	-	-	800
Supplies	2,000	-	-	2,000
Other	-	-	12,500*	12,500
Total	21,000	25,000	14,500*	60,800

* Iowa Egg Council

Budget Explanation

In the FY 2001, the funds from the Leopold Center will be used to support 44% time of the graduate student assistantship. Other 6% time of the assistantship will be supported from funds provided by Iowa Egg Council. Hourly money will be used to hire a part time student to work with the graduate student in sample collection and laboratory analyses for NO_3-N, PO_4-P, and bacteria. The experimental site is about 10 miles from Ames and travel funds will be used to pay for mileage costs related to field data collection.