Nutrient Losses through Sub-surface Drainage in No-till Cotton in the Southern Piedmont

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ABSTRACT

Water infiltration and preferential flow typically increase when tillage is reduced or eliminated increasing the risk of potential contamination of ground water by nutrients, notably nitrate-nitrogen (NO_3-N). Leaching of dissolved ortho-phosphate (Ortho-P) can also be a concern when groundwater discharges into stream nearby. We conducted a study in 1997 and 1998 near Watkinsville, GA, to evaluate NO_3-N and Ortho-P losses through subsurface drainage from no-till (NT) and conventional tillage (CT) cotton fertilized with either conventional fertilizer (CF) or poultry litter (PL). There was no drainage in the 1998 cotton season due to limited rainfall. There was no difference in total NO_3-N loss between CT and NT in 1997 (mean 8.9 and 8.2 kg ha^{-1}, respectively; P>0.73). There was a difference between PL and CF (mean 10.3 and 6.5 kg $ha^{-1,}$ respectively, P=0.009). This may have been due to greater mineralization than expected from PL. Peak NO_3-N concentrations reached 20 to 30 mg L^{-1} from CT and 10 to 15 mg L^{-1} from NT plots during the first two months after N application, and then fell to below 5 mg L^{-1} late in the season. Peak concentrations were between 10 and 20 mg L^{-1} in both PL and CF plots, with that from PL being higher by up to 5 mg L^{-1}. Dissolved ortho-phosphate concentration remained below 0.1 mg L^{-1} for all but one drainage event. These are encouraging results for producers engaged in cotton production under no-till with poultry litter with respect to water quality.

INTRODUCTION

Economic, environmental and legislative issues facing farmers are changing traditional agriculture in North America and other parts of the world. Conservation tillage and use of animal waste as an alternative nutrient source are getting increased attention as avenues towards sustainable agriculture. The adoption of conservation tillage has grown steadily in north and south America in recent times. Conservation tillage is any tillage and planting system that leaves 30% or more of crop residue on the soil surface after planting (CTIC, 1998). A cover crop is usually required to achieve this level of residue. Benefits credited to conservation tillage include soil and water conservation, lower production costs, and greater production efficiency. The high residue cover and improved soil aggregate stability as a result of increased organic matter associated with conservation tillage can reduce soil erosion and increase water retention (Langdale et al., 1979). Infiltration rates are higher under conservation tillage because crop residues and more stable aggregates reduce crusting compared to conventional tillage, and because of increased numbers of macropores (Adreini and Steenhouse, 1990; Golabi et al., 1995; Radcliffe et al. 1988). Reduced erosion and increased water retention might decrease the sediment-bound pollutants to surface waters helping water pollution containment efforts.

Greater infiltration and macropore frequency may, however, cause accelerated leaching of groundwater contaminants. There is a prevalence of elevated NO_3-N concentrations in ground waters in watersheds of intensive agricultural use (Heathwaite, 1995; Mueller and Helsel, 1996; NRC, 1993). The type of tillage, as well as source and rate of fertilizer may influence the quantity of nutrients moving through the soil profile. More rapid leaching of solutes in no-till compared to conventional tillage have been found in some soils (Adreini and Steenhouse, 1990; Dalal, 1989), but other studies have found the reverse (Kanwar, 1991, Shipitalo and Edwards, 1993). McCracken et al., (1995) found that NO_3-N leaching losses tended to be greater under no-till compared to conventional tillage only when rainfall occurred soon after fertilizer application.

Much of the row crop agriculture in the southeastern USA is conventionally tilled and fertilized. However, adoption of conservation tillage for major crops such as cotton and soybean have risen to about 12 and 25% of the cropped area, respectively (CTIC 1998). There is a coordinated national drive in the USA to increase the use of conservation tillage to 50% of the cropped area by 2002 (CTIC, 1998). Cotton and poultry production are of great economic importance in the Southeast (Rodekhor and Rahn, 1997) and rapid growth is projected for both. Close to 0.62 million hectares of cotton was grown in Georgia in 1995 compared to 0.11 million hectares in 1985. Large quantity of litter is produced from the poultry industry. Poultry litter is typically applied to pasture and crop land because it contains the plant nutrients N, P, and K (Moore et al., 1995). As the poultry industry continues to expand, application of poultry litter to agricultural lands will increase because it is considered to be a safe practice (Edwards and Daniels, 1992).

The water quality impact of cotton production on the dominant soils in the Southeast under different tillage and nutrient management systems is not well understood and documented. The object of this study was to quantify sub-surface NO_3-N and Ortho-P losses form a summer cotton and winter rye cropping system under a factorial arrangement of no-till, conventional tillage, conventional fertilizer, and poultry litter on a Cecil soil of the Southern Piedmont.

MATERIALS AND METHODS

The experiment was conducted in 1997 and 1998 at the USDA-ARS, J. Phil Campbell Sr. Natural Resource Conservation Center, Watkinsville, GA (33º54' N lat and 83º24' W long) as a completely randomized block design with a factorial combination of tillage (no-till (NT), vs conventional-till (CT)) and fertility source (ammonium nitrate, as conventional fertilizer (CF), vs poultry litter (PL)). Each treatment was replicated three times. The site consisted of 12 instrumented and tile-drained 10-m x 30-m plots, located on nearly level (0-2%) slope Cecil sandy loam (clayey, kaolinitic, thermic Typic Kanhapludults). Five 30-m long drain lines made of flexible, slotted 102-mm (4") diameter PVC were installed in each plot spaced 2.5 m apart and on a 1% grade, 0.75 m at the shallow end, and delivered the drainage to a collector drain for measurement. Plots were isolated from lateral flow by polyethylene sheeting installed around each plot to the depth of the drain lines.

Tillage treatment was started on the 12 plots in April 1992 in connection with another study. The CT treatment consisted of chisel plowing and disking, while NT consisted of coulter planter use only. Fertilizer rates were: poultry litter, 4.5 Mg ha^{-1} (2 tons $acre^{-1}$ 30% moisture basis; equivalent to about 60 kg available N ha^{-1}), and ammonium nitrate 60 kg available N ha^{-1}. The source of poultry litter was a local poultry house that generates 3 flocks per cleaning from concrete floor covered with saw-dust and shavings. Laboratory analysis showed that total N applied from poultry litter was 131 kg ha^{-1} in 1997, and 120 kg ha^{-1} in 1998. We assumed 50 percent of the litter mineralized during the crop season. Potassium was applied based on soil test results. Phosphorus was not applied as soil test results established no need. Pesticides and fertilizers were applied before planting and were incorporated into the soil by light disking immediately afterwards in CT but not in NT plots.

Stoneville 474 variety cotton was planted on 14 May both in 1997 and 1998, and harvested on 4 November 1997, and 12 November 1998. Rye was grown as cover crop each winter and received about 50 kg available N ha^{-1} as ammonium nitrate in all plots just before planting, and was chemically killed about two weeks before planting of cotton. Drainage from each plot was measured by tipping buckets, and recorded digitally with Campbell CR10X data loggers. About 275 mL of the drainage was automatically collected for every 600 L of flow and stored under refrigeration ($4^{O}C$) in the field by ISCO model 3700 FR sequential water samplers until taken to the laboratory for filtration and NO_3-N and Ortho-P analysis. Data were analyzed with the General Linear Models Procedure of SAS (SAS Inst., 1989).

RESULTS AND DISCUSSION

Total nitrate loss from each treatment during the 1997 cotton crop season is shown in Table 1a. Statistical significance (P values) are given in Table 1b. There was no difference in NO_3-N loss between no-till and conventional tillage treatments at $P< 0.05$ level (CT vs NT, CTCF vs NTCF, CTPL vs NTPL, $P>0.699$). Poultry litter increased NO_3-N loss compared to conventional fertilizer - significant at $P<0.05$ level (CF vs PL, CTCF vs CTPL, NTCF vs NTPL, $P<0.049$). The mean difference in NO_3-N loss between fertilizer sources was, however, relatively small (CF vs PL, 3.8 kg ha^{-1}; CTCF Vs CTPL, 4.0 kg ha^{-1}; NTCF vs NTPL, 3.5 kg ha^{-1}; CTCF vs NTPL, 3.4 kg ha^{-1}).

Table 1a. Total nitrate load in kg ha^{-1} in 1997 from conventional tillage CT, no-till NT, conventional fertilizer CF, poultry litter PL, and CTCF, CTPL, NTCF, NTPL treatments.

	Treatment							
REP	**CT**	**NT**	**CF**	**PL**	**CTCF**	**CTPL**	**NTCF**	**NTPL**
	NO_3-N Load kg ha^{-1}							
1	**6.17**	**6.27**	**6.17**	**11.82**	**6.17**	**11.82**	**6.27**	**6.74**
2	**8.18**	**6.91**	**8.18**	**9.35**	**8.18**	**9.35**	**6.91**	**12.83**
3	**5.42**	**6.22**	**5.42**	**10.54**	**5.42**	**10.54**	**6.22**	**10.35**
4	**11.82**	**6.74**	**6.27**	**6.74**	-	-	-	-
5	**9.35**	**12.83**	**6.91**	**12.83**	-	-	-	-
6	**10.54**	**10.35**	**6.22**	**10.35**	-	-	-	-
Mean	**8.58**	**8.22**	**6.52**	**10.27**	**6.59**	**10.57**	**6.47**	**9.97**
Std. Dev.	**2.48**	**2.73**	**0.93**	**2.11**	**1.43**	**1.23**	**0.38**	**3.06**
Std. Err.	**1.01**	**1.11**	**0.38**	**0.86**	**0.82**	**0.71**	**0.22**	**1.77**

Since higher NO_3-N losses occurred in both tillage treatments with poultry litter, the difference may have been due to greater N mineralization than expected from poultry litter. In our calculation, we had assumed that 50% of the organic N in poultry litter would be mineralized in a year. Vest et al., (1994) indicate N availability of 50 and 60% from broadcast and soil incorporated in-house or stockpiled litter, respectively.

Nitrate-nitrogen concentrations of the draining water during and just after the 1997 cotton season are shown in Figures 1 and 2. Before the application of N on May 14, 1997, NO_3-N concentrations in draining water were below 3 mg L^{-1} in all treatments. During the first two months after N application, concentrations increased to 20 to 30 mg L^{-1} from CT and 10 to 15 mg L^{-1} from NT plots.

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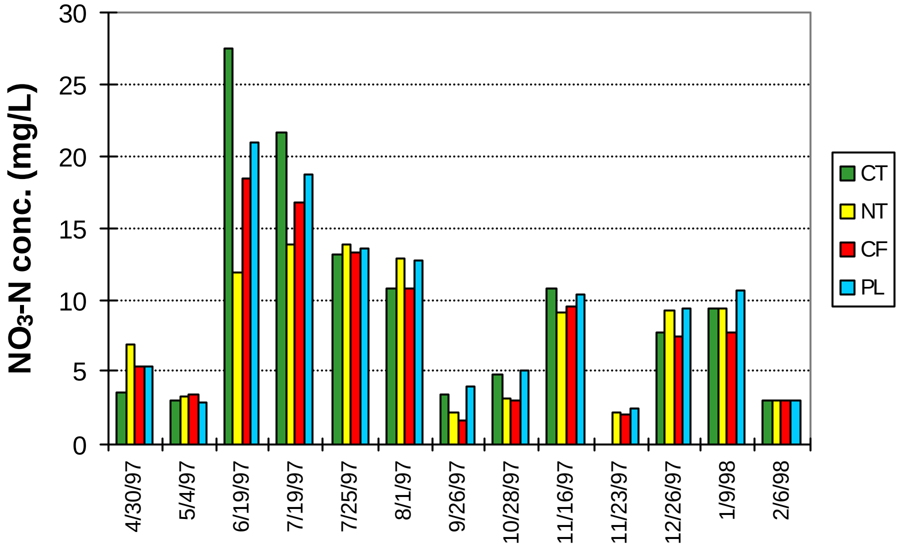
Table 1b. Statistical significance (P values) for total nitrate load in kg ha^{-1} in 1997 from conventional tillage CT, no-till NT, conventional fertilizer CF, poultry litter PL, and CTCF, CTPL, NTCF, NTPL treatments.

EFFECT	P value	Significance†
CT vs NT	**0.741**	**NS**
CF vs PL	**0.009**	**}**
CTCF vs CTPL	**0.031**	**}**
CTCF vs NTCF	**0.936**	**NS**
CTCF vs NTPL	**0.056**	**NS**
CTPL vs NTCF	**0.023**	**}**
CTPL vs NTPL	**0.699**	**NS**
NTCF vs NTPL	**0.049**	**}**

† NS, not significant at P<0.05; } significant at P<0.05



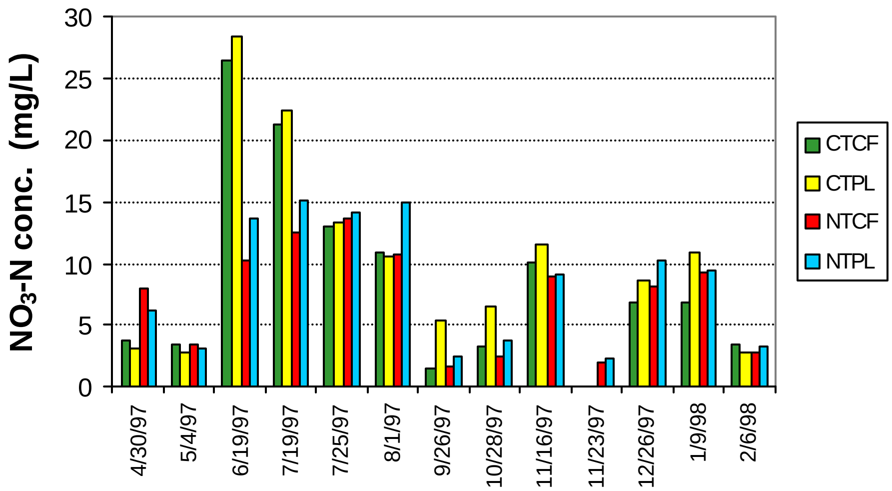


Fig. 1. Mean nitrate-nitrogen concentrations of drainage water from conventional tillage (CT), no-till (NT), conventional fertilizer (CF) and poultry litter (PL) treatments during the 1997/1998 cotton and rye season. Fertilizer application dates were 5/12/97 for cotton and 11/14/97 for rye.

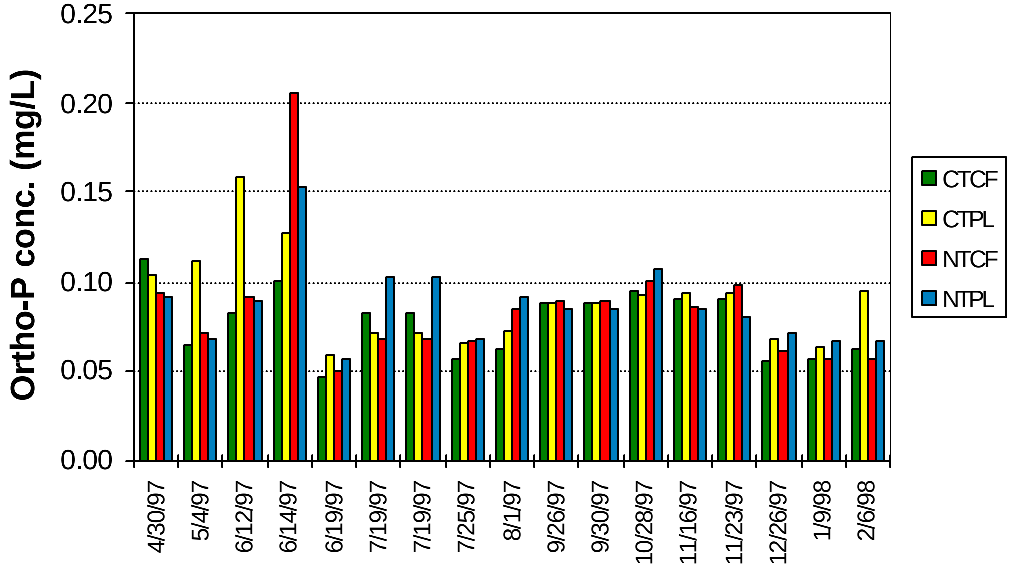


Fig. 2. **Mean nitrate-nitrogen concentration of drainage water from conventional tillage and conventional-fertilizer (CTCF), conventional tillage and poultry litter (CTPL), no-till and conventional fertilizer (NTCF), and no-till and poultry litter (NTPL) treatments during the 1997/1998 cotton and rye crop season. Fertilizer application dates were 5/12/97 for cotton and 11/14/97 for rye.**

Fig. 3. Mean Ortho-P concentration of drainage water from conventional tillage and conventional-fertilizer (CTCF), conventional tillage and poultry litter (CTPL), no-till and conventional fertilizer (NTCF), and no-till and poultry litter (NTPL) treatments during the 1997/1998 cotton and rye crop season. Fertilizer application dates were 5/12/97 for cotton and 11/14/97 for rye.

The PL treatments in each group showed up to 5 mg L^{-1} higher NO_3-N concentrations than the CF treatments. By late September, concentration had decreased to about 5 mg L^{-1} or below in all treatments. The N application to the cover crop increased NO_3-N concentration to about 10 mg L^{-1} during December 1997 and January 1998, which then fell below 5 mg L^{-1} in early February 1998.

Dissolved ortho-phosphate concentration remained between 0.05 and 0.1 mg L^{-1} in 1997 except for the first drainage event in mid-June where concentration reached 0.15 mg L^{-1} for the PL and 0.2 mg L^{-1} for the NTCF treatment (Figure 3). Mean Ortho-P loadings in kg ha^{-1} were: CT, 0.12; NT, 0.14; CF, 0.13; PL, 0.14; CTCF, 0.12; CTPL, 0.12; NTCF, 0.14; and NTPL, 0.15.

In 1997, the first drainage event occurred 35 days after planting reported as that of June 19, 1997 in Figures 1 and 2. And then almost another month went by before the second drainage event followed. There was no significant drainage in 1998 and thus we collected little effluent. Rainfall was about 140 mm below normal for May through November, with a deficit in each month. Most rainfall events were below 25 mm, the approximate threshold above which drainage was observed in 1997

SUMMARY AND CONCLUSIONS

There is a worldwide concern about contamination of water resources by nutrients such as NO_3-N and Ortho-P from non-point sources. This research compared sub-surface losses of NO_3-N and Ortho-P from cotton managed under no-tillage and fertilized with poultry litter versus that from conventionally-tilled and fertilized cotton. The study was conducted at the USDA-ARS facility near Watkinsville, GA in 1997 and 1998. The site consisted of 12 instrumented tile-drained plots each 10-m x 30-m on nearly level (0-2% slope) Cecil sandy loam. The four treatments were replicated three times. Cotton was grown in summer followed by rye as cover crop in winter.

There was no drainage in 1998 due to limited rainfall. In 1997 there was drainage and no-till did not increase NO_3-N loss when compared to conventional tillage. Poultry litter led to a larger NO_3-N loss than conventional fertilizer probably due to higher than expected N mineralization rate. Dissolved ortho-phosphate concentration generally remained between 0.05 and 0.1 mg L^{-1}. Concentrations reached 0.15 and 0.2 mg L^{-1} in mid-June for the poultry litter and conventional tillage/fertilizer treatments, respectively. The first drainage event occurred one month after planting. No-till cotton fertilized with poultry litter does not appear to have adverse NO_3-N and Ortho-P leaching impacts from a Cecil soil of the Southern Piedmont. Endale et al., (2000) report in these proceedings that lint yield from no-till and no-till-poultry-litter cotton exceeded that from conventional tillage and conventional-tillage-conventional-fertilizer cotton by 32 and 43%, respectively. These are encouraging results to those producers managing cotton under no-till with poultry litter in the Southeast.

ACKNOWLEDGMENTS

Funding for the research came from the USDA Cooperative State Research Service NRICGP Water Resources Assessment Protection Program and the Southeast Egg and Poultry Association. We greatly appreciate the assistance by C. Bokey, J. Doster, T. Foard, S. Noris, M. Mathis, B. Nutt, D. Stark, L. Robichaux, R. Woodroof and students from the Crop and Soil Science Department of the University of Georgia.

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