Tillage and Cover Crop Effects on Nitrate Leaching

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INTRODUCTION

In no other part of the United States is the erosion potential worse than in the western parts of Kentucky and Tennessee. It is an area of sloping loessial soils, with high rainfall intensities, and a high proportion of the area in row crops. No tillage (NT) has been adopted by many farmers in the area to control erosion. The no-tillage system has proven its effectiveness in reducing overland flow and sedimentation (Blevins, et al., 1989; Shelton, et al., 1983).

There is a tendency for macropores to form under NT. These macropores may be root channels, cracks between soil ped faces or earthworm burrows (Thomas et al., 1973; Thomas and Phillips, 1979; Edwards et al., 1988). Macropores potentially increase the amount of water entering the soil. This infiltration increase combined with lower evaporation from the soil surface under NT potentially leads to higher leaching. The effect of tillage on macropores and the flow of water and chemicals through macropores has been shown to be important (Thomas et al., 1973; Quisenberry and Phillips, 1976; Edwards, et al., 1988). In earlier lysimeter work at Lexington, Ky, Tyler and Thomas (1979) showed a tendency for more NO_3-N and Cl loss from no-tillage during the spring, but practically no difference during winter. However, Kanwar et al. (1985) concluded that increased macroporosity under NT results in decreased nitrogen leaching when the nitrogen source is within micropores. Under the latter scenario, new water entering the soil during storm events by-passes the solute-rich micropores via macropore flow.

No-tillage cropping is especially important with double-crop soybeans (48 and 80% planted to no tillage in Tennessee and Kentucky, respectively) and to a lesser extent with corn (Anon., 1988). The use of no-tillage cultural practices for cotton production is relatively new and little is known about how tillage systems influence nitrate movement in the soil and its potential to pollute the groundwater. The general objectives are to determine the effects of cropping systems and tillage practices on nitrate movement. Specifically we are comparing nitrate leaching under (i) NT and CT (conventional tillage) cotton with no-cover in Tennessee, (ii) NT and CT soybean-wheat-corn rotation in Tennessee and Kentucky, (iii) continuous NT corn planted in wheat, hairy vetch, and no cover in Tennessee, and in hairy vetch and no cover in Kentucky, and (iv) alternating NT corn-soybean in Kentucky. An additional objective is to evaluate the preferential flow under such systems by comparing leachate measurements from three size lysimeters and by comparing infiltration properties and dye staining patterns under saturated and unsaturated conditions.

PROCEDURES

Tension-free pan lysimeters were used to collect water draining from the soil profile. Three sizes of lysimeters (75 x 60 cm, 45 x 35 cm, and 30 x 13 cm) were used in the NT corn with hairy-vetch cover in Tennessee. The large pans were used in all other studies in Tennessee arid Kentucky. Pans were installed under undisturbed soil at 90 cm depth by digging a trench into each plot and excavating laterally from the trench into the plot. A lysimeter was inserted into the excavated area with the outer edge at least 15 cm from the trench face into the plot. Each lysimeter was filled with sand and

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crushed marble to establish continuity with the soil profile. Tygon tubing was connected to the lysimeter to route water collected into a buried 60 L polypropylene carboy. Installation of all lysimeters was completed in May 1990 and leachate has been collected following storm events since that time. Nitrate concentrations and the quantity of subsurface flow has been recorded. Soil samples were collected at 15 cm intervals to a depth of 107 cm under each cropping system and resident nitrate and ammonium concentrations analyzed. Nitrate concentrations were determined by IC and ammonium by a colormetric method.

RESULTS AND DISCUSSION

Preliminary findings in Tennessee reveal that 81%of all the leachate samples had NO_3-N concentrations below the 10 mg L^{-1} maximum contaminant level (MCL) (Table 1). Samples exceeding the MCL typically occurred during the growing season shortly after fertilization when flow out of the root zone was generally small (Fig.l). The general pattern observed was high preferential flow out of the root zone during winter and early spring periods when nitrate-N concentrations were low. Nitrate-N concentrations were generally high during periods following fertilization, however, preferential flow during these summer periods was low or non-existent. Nitrate-N concentrations were generally higher under hairy vetch than under wheat or no cover during the winter period.

Table 1. Percentage of Tennessee samples with **NO_3-N concentrations above 10, 5, and 1 mg/L.**

Cropping System	10 mg/L	5 mg/L	1 mg/L
		%	
No-till Corn			
No-cover	4	12	65
Wheat	14	21	43
Hairy vetch	17	33	70
Cotton			
No-till	6	17	69
Chisel	14	42	72

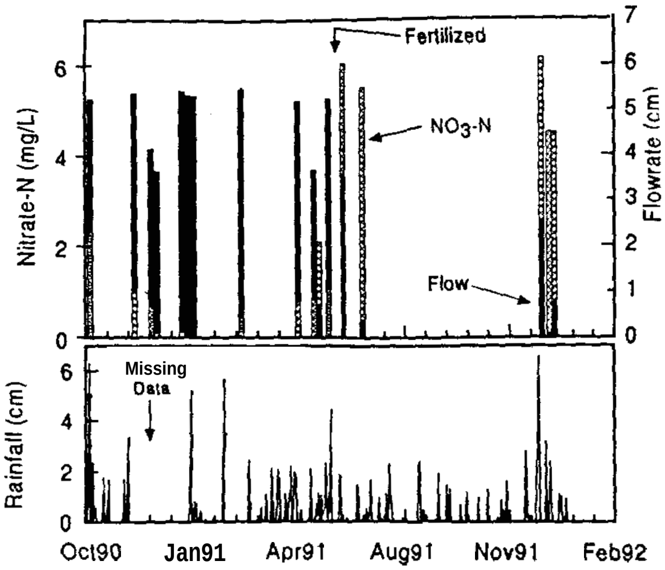


Fig. 1. Typical temporal variability of flow and nitrate-N concentration illustrated for NT corn with hairy vetch winter cover.

No-tillage appeared to reduce nitrate leaching under cotton (Fig. 2) and under the soybean-wheat-corn rotation during the wheat-corn period (Fig, 3) as compared to chisel plowing. Between 1 October 1990 to 31 September 1991 there were 30 and 20 kglha of N03-N leached for conventional and no-tillage cotton, respectively, and 14 and 5 kg/ha leached for conventional and no-tillage wheat-corn system, respectively. For no-tillage corn (Fig. 4), average losses of nitrate-N were greatest under hairy vetch (≈ 17 kgha), intermediate for winter wheat (≈ 10 kglha), and lowest under no cover (≈ 6 kg/ha). Nitrate-N losses ranged from 3 to **53** kg/ha with the 12 lysimeters under hairy-vetch cover. The small size lysimeter exhibited the greatest variability and greatest average loss (≈ 20 kglha), and the medium size had the lowest average loss (≈ 9 kg/ha).

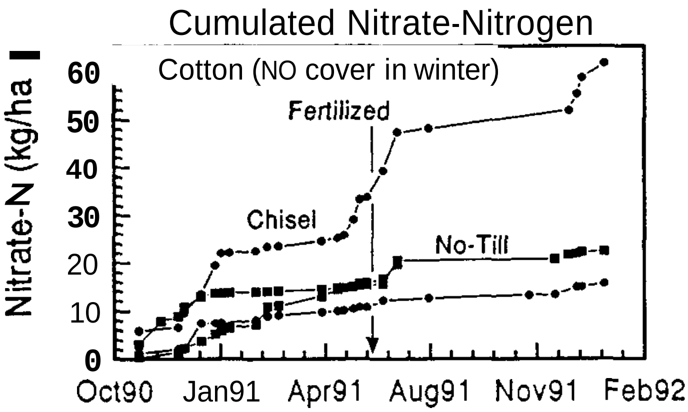


Fig. 2. Cumulative mass of nitrate-N transported out of the root zone per hectare under NT and CT cotton with no winter cover crop in Tennessee.

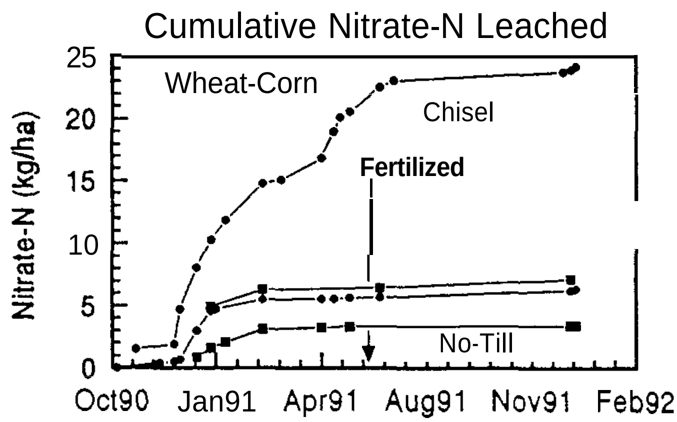


Fig. 3. Cumulative mass of nitrate-N transported out of the root zone per hectare under NT and CT soybean-wheat-corn rotation system in Tennessee.

First year results in Kentucky show that 80% of all leachate samples had N03-N concentrations below the 10 m,g/l MCL (Table 2). Corn with winter wheat that was fertilized with 150 kg N ha-1 during the summer lost about 40 kg ha^{-1} under no-tillage and 65 kg ha^{-1} under conventional tillage through the winter (Fig. 5). Conventional tillage exhibited greater nitrate leaching than NT until fertilization of wheat. When wheat was top-dressed in March with 75 kg ha^{-1} of nitrogen as ammonium nitrate and a rainstorm occurred the following night, both no-tillage and conventional-tillage wheat showed very large losses of 50 and 30 kg ha^{-1}, respectively, in a single storm. These results illustrate how highly susceptible nitrate is to leaching immediately following application. Losses of nitrate-N were small in the case of conventionally-tilled soybeans ($\approx$ 15kg ha^{-1}) and considerably higher with no-till soybeans ($\approx$ 35 kg ha^{-1}), Fig. 6. However, these differences were not apparent in the concentration data shown in Table 2.

CONCLUSIONS

For Tennessee and Kentucky, 81% and 80%, respectively, of leachate samples had NO,-N concentrations below the 10 mg L^{-1} MCL. Samples exceeding the MCL occurred during the growing season shortly after fertilization when flow out of the root zone was generally small. When large rainstorms occurred immediately following fertilization, as much as 50 kg/ha of NO_3-N was leached. Flow was greatest during the winter and spring when concentrations were below the MCL in Tennessee. In Kentucky, NO_3-N concentrations above 10 mg L^{-1} were observed on occasions throughout the year. No-tillage appeared to reduce nitrate leaching under cotton in Tennessee, and under corn systems in Tennessee and Kentucky. In Tennessee we observed that infiltration rates were relatively low with no significant differences between CT and NT. Thus, no-tillage not only improved surface water quality but did not increase the potential for leaching of chemicals toward groundwater due to greater infiltration. Losses

Table 2. Percentage of Kentucky samples with NO_3-N concentrations above 10, 5, and 1 mg/L.

Cropping System	10 mg/L	5 mg/L	1 mg/L
		%	
<u>Corn-Wheat</u>			
No-ti11	18	50	84
Conventional	26	43	90
<u>Soybean</u>			
No-till	2	25	95
Conventional	33	64	97

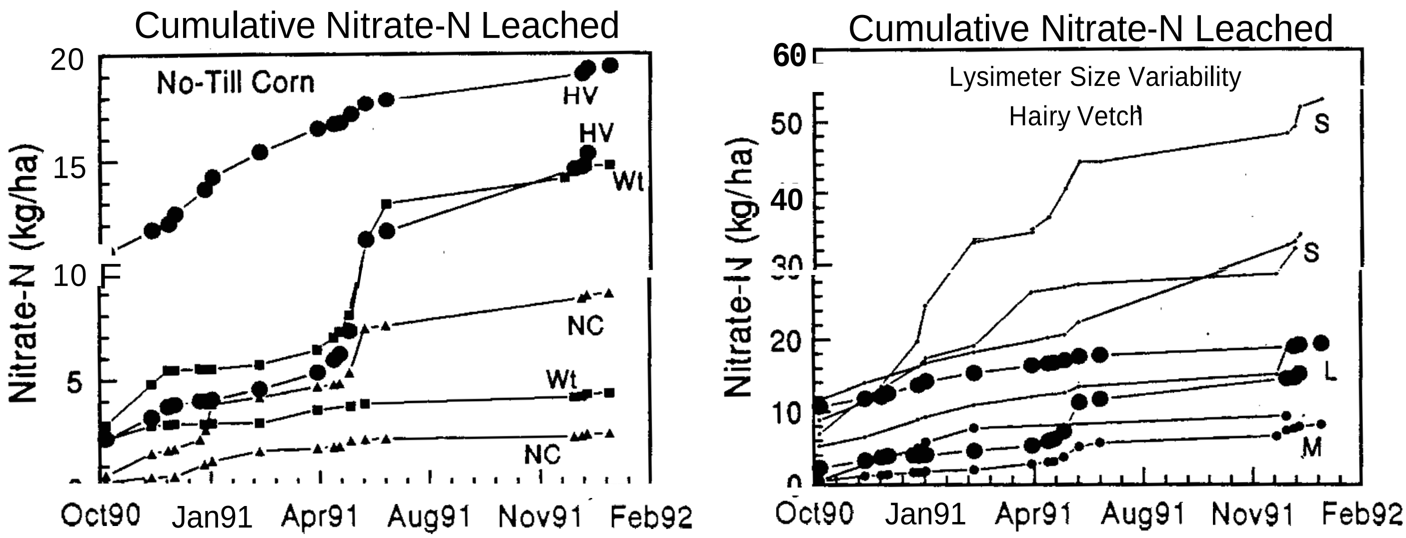


Fig. 4. Tennessee. Transport into a) large lysimeter pans under NT corn with hairy vetch (HV), winter wheat (Wt), and no cover (NC), and b) into large (L), medium (M) and small (S) pans under hairy vetch.

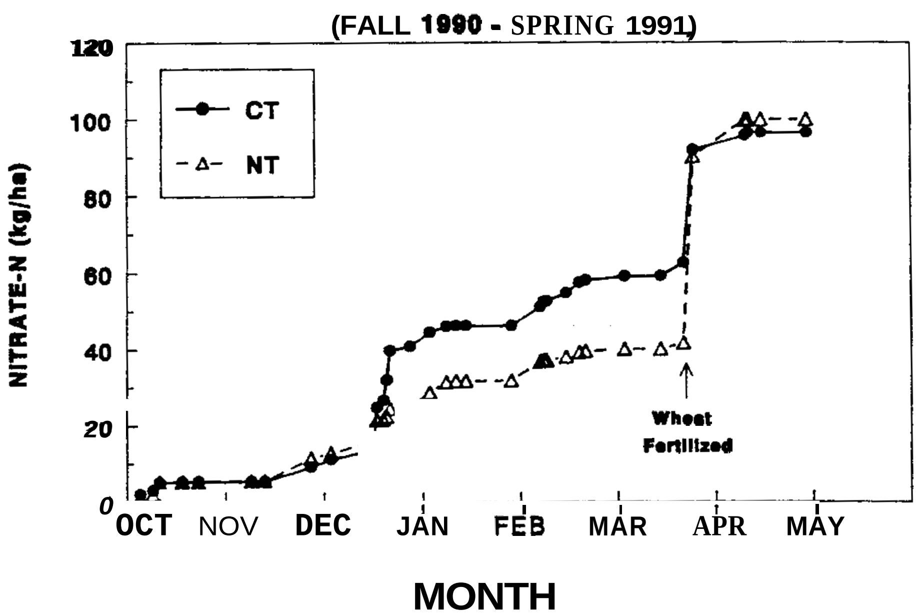
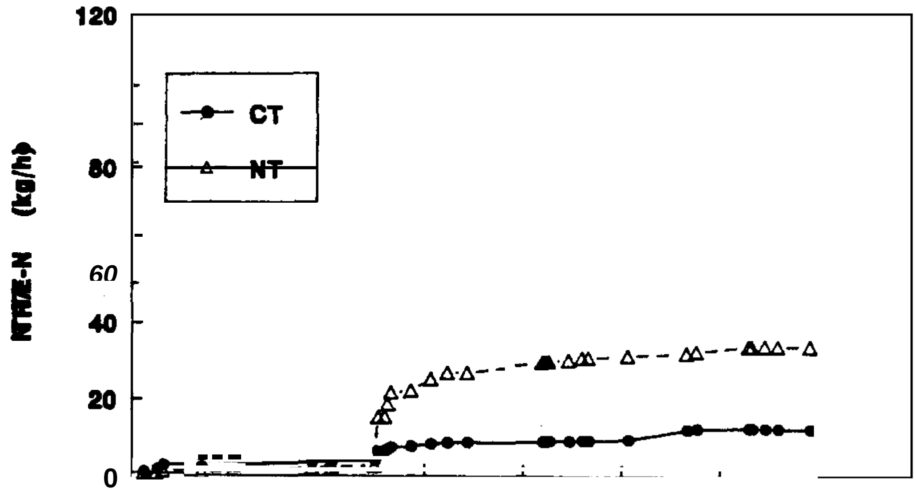


Fig. 5. Mass of nitrate-N transported out of the root zone per hectare under NT and CT Corn in Kentucky.



of NO_3-N under soybean systems were generally low, however, losses were higher with no-tillage than with conventional tillage.

ACKNOWLEDGEMENTS

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