MANAGEMENT EFFECTS ON NITROGEN AND PHOSPHORUS LOSSES IN RUNOFF ON EXPANSIVE CLAY SOILS

H. A. Torbert, K. N. Potter, J. E. Morrison Jr.

ABSTRACT. *Raised wide beds have been proposed as a conservation tillage practice for reducing erosion losses in vertisols, but few measurements of nitrogen (N) and phosphorus (P) losses have been reported. The objective of this study was to examine the impact of tillage systems and fertilizer N application methods on sediment and nutrient losses associated with interrill runoff. Simulated rainfall events (125 mm h^{-1} until 30 min of runoff had occurred) were applied to raised wide beds (0.15 m high and 1.5 m wide with 0.5-m-wide furrows) on a Houston Black clay (fine, montmorillonitic, thermic Udic Pellusterts) which had been managed with either a no-till or a chisel-till tillage system. Three simulated methods of applying fertilizer N (surface band, coulter-nozzle, or spoke wheel simulated field practices) were compared in a split plot experimental design with four replications. Total N and P losses, as well as fertilizer N losses, in both sediment and solution from interrill runoff were determined from 1 m^2 plots. While no P was applied in fertilizer, greater P losses were observed with the chisel-till compared to no-till. While N losses in runoff were relatively low, fertilizer N application with surface banding or the coulter-nozzle applicator in no-till had greater total N and fertilizer N losses. Under relatively wet soil water conditions, respective losses of total inorganic N and fertilizer N in solution were greater from no-till with 4.0 and 2.0 kg N ha^{-1} lost, as compared to 0.2 and 0.1 kg N ha^{-1} lost from chisel-till per rainfall event. Losses of N in sediment were greatest in chisel-till, with 2.1 and 0.03 kg N ha^{-1} lost from chisel-till, as compared to 0.6 and 0.01 kg N ha^{-1} lost from no-till, of total N and fertilizer N per rainfall event, respectively. The greatest N losses during the runoff event was observed with the surface banded and coulter-nozzle fertilizer application methods in no-till due to increased fertilizer N losses.* **Keywords.** *Nitrogen, Phosphorus, Tillage, Clay soil, Runoff.*

Because of the high erosion potential, efforts have been undertaken to develop conservation tillage systems for soils with high shrink/swell potential. These soils are difficult to manage because of their physical characteristics, including high water holding capacity, high plasticity, increased strength when dry, and a limited range of soil water content when soil tillage can be performed (Potter and Chichester, 1993). When wet, these soils have low infiltration rates which can lead to high runoff rates, and because such soils slake into fine aggregates, they are easily eroded. These characteristics lead to management difficulties when implementing conservation tillage practices for erosion control and environmental protection. A management system using raised wide beds has been proposed as a conservation tillage system for these soils (Morrison et al., 1990), utilizing furrows between beds as surface drainways and as controlled traffic lanes to support tractors during wet periods. While this system has been found to work fairly consistently (Morrison et al., 1994), no report of nutrient losses as affected by these tillage systems has been made.

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Because of possible human health risks and the eutrophication of surface waters, nonpoint source pollution of surface water from fertilizers or other agricultural inputs continues to be a major concern. Application of fertilizer in the most efficient manner possible is important so that farmers can optimize their profits and/or minimizing the potential pollution hazard.

Fertilizer application in conservation tillage is especially difficult, because of the need to limit disturbance of surface residues that provide erosion control. Under this tillage system, fertilizer is often applied to the soil surface to prevent such disturbance. Several studies have reported higher nutrient losses in runoff when fertilizer was applied to the soil surface as compared to subsurface fertilizer application (Beyrouty et al., 1986; Romkens et al., 1973; Timmons et al., 1973; Whitaker et al., 1978). For example, Beyrouty et al. (1986) reported a 20 to 40% increase in fertilizer recovery at the end of the year when urea-ammonium nitrate (UAN) solution was applied subsurface compared to surface application. Timmons et al. (1973) reported nutrient losses decreased with increased level of incorporation of applied fertilizers. Recently fertilizer application equipment has been developed that allows for subsurface application of fertilizers with minimal surface residue disturbance. For example, a spoke wheel applicator applies fertilizer solution with a point injection below the soil surface (Baker et al., 1985) and a coulter-nozzle shoots a solid stream of fertilizer into a slit opened behind a rolling coulter (Morrison and Potter, 1994). Morrison and Chichester (1988) examined several fertilizer knife designs and found that a coulter-nozzle fertilizer applicator made the least soil disturbance.

Recent research on a vertisol found little or no significant differences in agronomic response (grain yield and fertilizer efficiency as measured in grain yield) to eight different fertilizer application methods (Chichester and Morrison, 1992). While differences in fertilizer runoff losses due to application method may be too small to impact agronomic measures such as yield, impacts to water quality may be significant. The objective of this study was to examine the impact of tillage systems and fertilizer N application methods on interrill sediment and nutrient losses associated with runoff from rainfall events occurring shortly after fertilizer application.

Materials and Methods

A rainfall simulator was used to generate sediment and fertilizer N losses in runoff as affected by fertilizer application method and tillage systems on expansive clay soils. Tillage plots (four replications) under four years of continuous management at the Grassland, Soil and Water Research Laboratory (31°05′N, 97°20′W) on a Houston Black clay soil were utilized. Tillage plots (30.5 m long) consisted of either a chisel plow tillage system (chisel-till) or a no tillage system (no-till). The management system in these plots included raised wide beds 1.5 m wide, 0.15 m high, and separated by 0.5-m furrows (fig. 1) that act as traffic lanes and surface drainways (Morrison et al., 1990). Crop production in these beds consisted of a annual rotation of wheat (*Tritcum aestivum* L.), corn (*Zea mays* L.), and grain sorghum (*Sorghum bicolor* L.).

Percentage residue cover was determined by the number of residue hits by a 2-mm-diameter rod at 100 points located across two diagonal transect of the plot at the completion of rainfall simulation. This method is comparable to the point intercept method discussed by Morrison et al., 1993.

Rainfall simulation was imposed on plots in August 1993 following wheat production, simulating conditions expected for subsequent grain sorghum planting. The tillage associated with the chisel-till system was performed approximately two weeks before initiation of the study.

Three fertilizer N application methods were utilized to simulate the use of a surface banded application, a coulter-nozzle application, and a spoke wheel application. These fertilizer application methods are designed for fertilizer application with a minimal disturbance of the surface residues. Surface banded application entails direct application of metered streams of fertilizer solutions to surface soil and residues. The coulter-nozzle applicator allows for shallow subsurface application of fertilizer solutions by using a smooth rolling coulter with rotary scrapers to cut residue and open a soil slot while a hydraulic nozzle applies a solid stream of fertilizer solution into the slit (Morrison and Chichester, 1988). With the spoke wheel applicator, fertilizer solution is applied with a point injection below the soil surface (Baker et al., 1985). Fertilizer application was made in two bands across the plot area 40 cm apart and 30 cm from the side of the 1 m^2 study area for all three application methods (fig. 1).

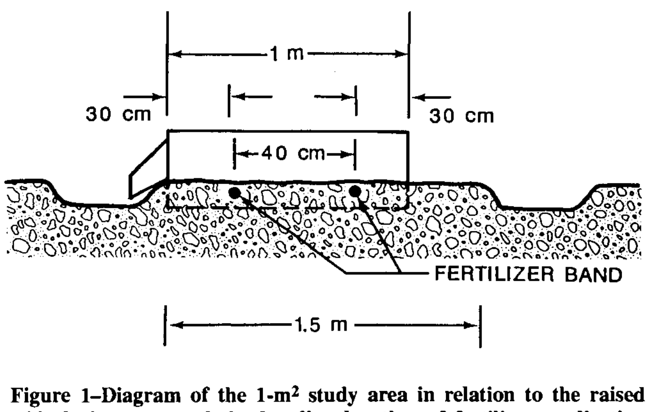

Figure 1–Diagram of the 1-m^2 study area in relation to the raised wide bed system and the banding location of fertilizer application treatments.

Application of fertilizer N was made at a rate of 135 kg N ha^{-1} in the form of UAN solution 320 (0,45,35), with 32% total N, of which 45% was ammonium nitrate and 35% was urea. In order to separate fertilizer N from resident soil N, the fertilizer solution was ^{15}N-enriched with 1.5 atom % ^{15}N for both the ammonium nitrate and the urea. Fertilizer application was made 24 h before initiation of rainfall simulation. Fertilizer application was made under dry soil water conditions because under normal operating conditions, the soil would have to be relatively dry to operate both the spoke wheel and the coulter-nozzle fertilizer application equipment. Simulated rainfall was initiated one day after application to provide a worse case scenario for fertilizer losses in these production systems.

The use of ^{15}N enriched fertilizer solution prohibited the use of production scale fertilizer application equipment, therefore, fertilizer was applied manually using techniques designed to simulate fertilizer application equipment. Banding of solution was simulated by depositing a solid stream of solution in a 3 to 5 mm band across the width of the 1 m^2 study area (fig. 1). Coulter-nozzle application was simulated by pressing a slot approximately 3 cm into the soil with a metal plate after the residue was cut and metering solution into the slot with a syringe, and pressing the slot paths closed. A modified pistol grip veterinary medicine syringe as described by Benjamin et al. (1988) was used to simulate the spoke wheel fertilizer application equipment by insertion of the syringe to a depth of 15 cm.

A rainfall simulator, similar to that described by Miller (1987), used a Spraying Systems wide square spray 30 WSQ nozzle at a nominal rate of 125 mm h^{-1} producing approximate rainfall conditions of a 10-year, 30-min rain for Bell County, Texas. Dropsize was 2.5 mm and kinetic energy was 23 J m^{-2} mm^{-1}. A 1-m^2 area plot located on top of the raised bed was surrounded by a metal frame driven 0.1 m into the soil to define the study area (fig. 1). Rainfall application was made to a 10-m^2 area around the study area. The rainfall simulator, using water from the station irrigation system, was calibrated before each simulation run and a water sample was collected for background level correction of phosphorus (P) and nitrogen (N). The 1 m^2 study area would be substantially a measure of the interrill erosion. In addition, because surface drainage in this system moves into furrows which conducts water off the field (fig. 1), sediment and nutrient losses measured in the 1-m^2 study area would also be reflective of most of the losses that would occur in this system.

Rainfall was simulated under relatively dry soil water (dry run) and relatively wet soil water conditions (wet run). Gravimetric water content was measured before each rainfall simulation (fig. 2). Rainfall was initiated under ambient dry conditions and continued until 30 min of runoff had occurred. After 48 h, simulated rainfall was applied to the relatively wet condition, until 30 min of runoff had occurred. No natural rainfall occurred during the 48 h separating dry and wet runs during the course of the study. Runoff samples were sequentially collected from the downslope edge of the study area every 10 min for the dry run and every 5 min for the wet run. Runoff rates were determined by monitoring time needed to collect 1-L runoff samples.

Sediment content in each runoff sample was separated from solution to determine total sediment load. Total N and total P content of sediment was determined colorimetrically on a Technicon Autoanalyzer, following digestion of sediment by a salicylic acid modification of a semimicro-Kjeldahl procedure (Technicon Industrial Systems, 1976). Runoff solution was colorimetrically analyzed for NO_3-N, NH_4-N, and PO_4-P concentration using a Technicon Autoanalyzer (Technicon Industrial Systems, 1973). The solution content of NO_3-N, NH_4-N, and PO_4-P was calculated by multiplying the solution concentration by the water volume during each sample increment. Solution samples were corrected for background PO_4-P, NO_3-N, and NH_4-N content. Sediment and solution samples were prepared for N isotope-ratio analyses by the microdiffusion method as described by Liu and Mulvaney (1992), and analyzed using an automated mass spectrometer (Nuclide model 3-60-RMS; Measurement and Analysis Systems, Bellefonte, Pa.).

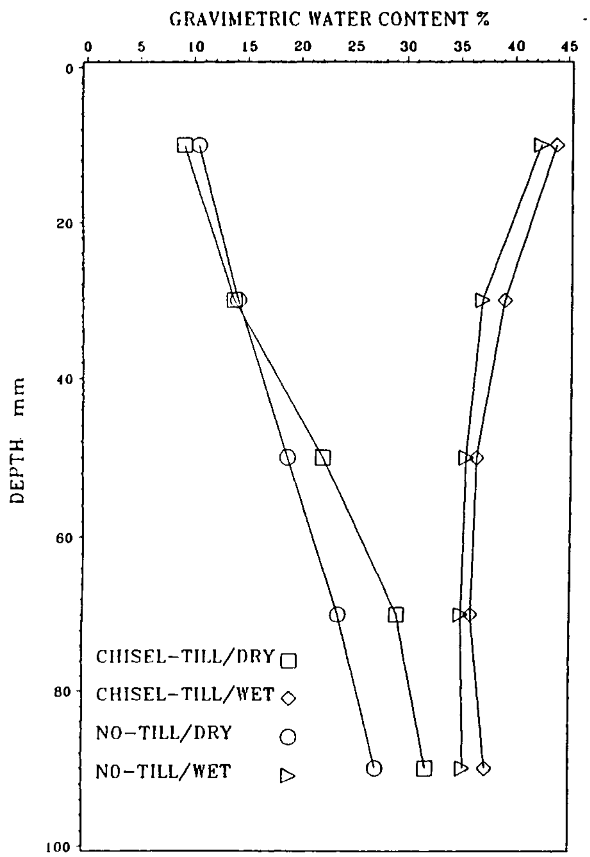

Figure 2–Soil water contents before and two days after the first rainfall simulation treatment.

The experimental design was a split plot with four replications, where main plots were two tillage systems and the subplots were three fertilizer N application methods. Data were analyzed using ANOVA procedures and means were separated using a protected least significant difference (LSD) at 10% probability level (Statistical Analysis Systems Institute, 1982). The term "trend" is used to designate appreciable nonsignificant treatment effects with probabilities above 10%. The term "*fertilizer N*" is used to denote N content originating from fertilizer N application. The term "*native soil N*" is used to denote N content from sources other than fertilizer N application. The terms "*total N lost*" and "*total P lost*" in runoff is N and P contained in both soluble and sediment-transported forms.

RESULTS AND DISCUSSION

SEDIMENT LOSSES

Percent residue cover in the no-till treatment averaged 99.3% with a standard deviation of 1.5, while the chisel-till treatment had an average percentage residue cover of 30.0% with a standard deviation 8.6. The high percent residue cover measured in the chisel-till treatment (above 30% cover is usually used to define conservation tillage systems) was due to the large volume of residue mixed into the soil when chiseled and consisted mostly of small particles left on the soil surface.

While not significant, total runoff volume tended to be greater with chisel-till compared to no-till (table 1). Differences in runoff volume between chisel-till and no-till tillage systems have been reported in the Houston Black clay soil (Potter et al., 1996), with differences caused by larger infiltration rates with the presence of crop residues. Sediment losses were greater with chisel-till compared to no-till in the wet run and the dry run (table 1), with sediment losses as much as 30-fold greater with chisel-till. Fertilizer application method did not affect sediment amounts lost during simulated rainfall events. This indicated that soil disturbance during fertilizer application was not sufficient to impact sediment losses with either the simulated coulter-nozzle or the simulated spoke wheel application.

Along with increased sediment losses, total N and total P losses in sediment were increased with chisel-till as

Table 1. Influence of tillage system on runoff, sediment, total P, total N, and fertilizer N content lost in sediment during rainfall simulation under dry and wet soil water conditions averaged over fertilizer application methods*

Tillage	Water Volume (m^3 ha^{-1})	Sediment (kg ha^{-1})	Sediment P (kg ha^{-1})	Sediment N (kg ha^{-1})	Fertilizer N (kg ha^{-1})
		Dry Run			
No-tillage	75 a	40 a	0.05 a	0.12 a	0.002 a
Chisel-tillage	99 a	1228 b	0.75 b	1.51 b	0.015 b
		Wet Run			
No-tillage	190 a	83 a	0.21 a	0.57 a	0.009 a
Chisel-tillage	231 a	1699 b	1.04 b	2.09 b	0.031 b

* Values represent means of four replicates. Values followed by the same letter do not differ significantly (0.10 level).

compared to the no-till (table 1). Also, as with total N content, fertilizer N losses were increased with chisel-till compared to no-till under the dry soil conditions (table 1). These findings agree with research reported by Chichester and Richardson (1992), which indicated that no-till reduced losses of sediment and nutrients from a vertisol when measured on a water shed scale.

For the wet run, a significant interaction between tillage systems and fertilizer application method was observed. The surface banded fertilizer N application method with chisel-till resulted in significantly higher fertilizer N content in runoff sediment compared to the other tillage and fertilizer application treatments (table 2). While the difference in fertilizer N in sediment was impacted by tillage and application method, with as much as an 18 fold increase, the amount of fertilizer N in sediment was small, with only one to three percent of the total N in sediment attributable to the fertilizer N applied. Because fertilizer N was such a small proportion of the total N in sediment, no significant difference in fertilizer N application method was observed for total N in sediment.

Solution Losses

For the wet run, differences in tillage systems and simulated fertilizer application methods were observed for inorganic N content and fertilizer N content in runoff solution. A significant interaction between tillage treatment and fertilizer N application method was observed for NO_3-N and NH_4-N content in runoff solution (table 3). Unlike N losses in sediment, the no-till tillage system increased NO_3-N content in runoff solution (table 3), with a 22-fold increase in NO_3-N content when averaged over fertilizer application method. While no difference in fertilizer application method was observed for NO_3-N content with chisel-till, the application method impacted NO_3-N content in no-till, with the spoke wheel application method reducing the NO_3-N content compared to surface banded and coulter-nozzle (table 3).

The coulter-nozzle in the no-till tillage system increased NH_4-N content in runoff solution compared to the coulter-nozzle with chisel-till and the spoke wheel in both tillage systems (table 3). There was no difference between surface banded application and any of the other fertilizer N application methods. Even though 72% of the N fertilizer applied was in the NH_4 form, the NH_4-N content in runoff solution was generally smaller than that of NO_3-N, especially with no-till, with only 6% of the total inorganic N in runoff solution in the NH_4 form in no-till compared to 35% with chisel-till. This was likely due to NH_4 being bound to soil regardless of the fertilizer application method. Volatilization losses of NH_4 may have also contributed to low NH_4 content in runoff (Jones, 1982).

Table 2. Influence of tillage system and fertilizer N application method on fertilizer N lost in sediment during rainfall simulation for wet run*

Tillage	Surface Banded	Coulter-Nozzle	Spoke Wheel	Mean
	Fertilizer N (kg ha^{-1})			
No-tillage	0.012	0.012	0.003	0.009 a
Chisel-tillage	0.055	0.021	0.013	0.031 b
Mean	0.034 a	0.016 b	0.008 b	
$LSD_{0.10}$ (any two means)	= 0.033			

* Values represent means of four replicates. Values followed by the same letter do not differ significantly (0.10 level).

Table 3. Influence of tillage system and fertilizer N application method on NO_3-N and NH_4-N in runoff solution for wet run*

Tillage	Surface Banded	Coulter-Nozzle	Spoke Wheel	Mean
	N (kg ha^{-1})			
NO_3-N				
No-tillage	4.92	4.28	2.15	3.79 a
Chisel-tillage	0.16	0.07	0.27	0.17 b
Mean	2.54 a	2.17 a	1.21 b	
$LSD_{0.10}$ (any two means)	= 1.65			
NH_4-N				
No-tillage	0.23	0.42	0.09	0.25 a
Chisel-tillage	0.22	0.02	0.03	0.09 a
Mean	0.23 a	0.22 a	0.06 b	
$LSD_{0.10}$ (any two means)	= 0.26			
Total Inorganic N				
No-tillage	5.16	4.71	2.23	4.03 a
Chisel-tillage	0.36	0.08	0.28	0.24 b
Mean	2.76 a	2.39 a	1.21 b	
$LSD_{0.10}$ (any two means)	= 1.85			
Fertilizer N				
No-tillage	2.93	2.39	0.68	2.00 a
Chisel-tillage	0.12	0.01	0.11	0.08 b
Mean	1.52 a	1.20 a	0.40 b	
$LSD_{0.10}$ (any two means)	= 1.09			

* Values represent means of four replicates. Values followed by the same letter do not differ significantly (0.10 level).

In the chisel-till system, the total inorganic N content of runoff solution was lower compared to no-till, but no differences were ascertained between simulated fertilizer N application methods (table 3). Differences were observed between simulated fertilizer N application methods within the no-till system, with the spoke wheel application significantly reducing total inorganic N content in runoff solution compared to surface banded or coulter-nozzle.

The fertilizer N content in the runoff solution was higher for the surface banded and coulter-nozzle application method within the no-till treatment compared to the other tillage and application method treatments (table 3). Also, the proportion of fertilizer N in the runoff solution for these two treatments was higher compared to the other treatments, with approximately 51 to 57% of total inorganic N attributable to fertilizer N compared to approximately 30% for most of the other treatments. The fertilizer N content of runoff solution for the spoke wheel treatment in no-till was not higher than the fertilizer N content in runoff of the chisel-till plots.

The P content in runoff solution was increased with the no-till system compared to the chisel-till system, with 0.14 and 0.03 kg PO_4-P ha^{-1} for no-till and chisel-till respectively. With chisel-till, the PO_4-P content in runoff solution was relatively constant, varying between 0.004 and 0.008 kg PO_4-P ha^{-1} during the 30-min runoff event (fig. 3). No-till on the other hand continued to increase in PO_4-P content for the entire 30-min runoff event, increasing from 0.004 kg PO_4-P ha^{-1} at 5 min to 0.041 kg PO_4-P ha^{-1} at 30 min. This could have been partially due to higher P concentrations in the top 15 cm of soil and a higher concentration of P in the sediment with

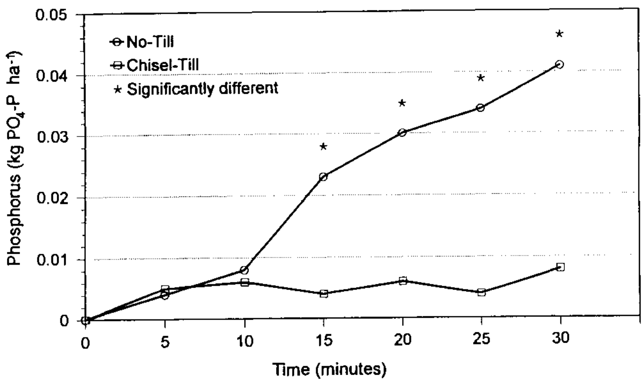

Figure 3–Effect of tillage system on PO_4-P content of runoff solution during a 30 min runoff event. Means are of four replications and an asterisk denotes means with significant differences.

no-till compared to chisel-till. The P concentration in soil averaged 0.67 and 0.56 g kg^{-1} and the P concentration of sediment averaged 0.88 and 0.62 g kg^{-1} for no-till and chisel-till, respectively. A likely cause of this effect was the leaching of P out of the plant residue during the rainfall event. Plant residue averaged 0.71 g P kg^{-1} of plant material. This observation agrees with other research which indicates that no-till will increase the level of PO_4-P in solution (Romkens et al., 1973; McDowell and McGregor, 1980; McDowell and McGregor, 1984). Increase of PO_4-P in runoff solution have been attributed to leaching of P out of the plant material exposed to rainfall (McDowell and McGregor, 1980; Schreiber, 1985; Schreiber and McDowell, 1985). However, Chichester and Richardson (1992) reported that while not significant, means for soluble P losses were higher in conventional tillage compared to no-till when measured from water sheds of a vertisol over a year period. This indicates that the relative importance of nutrient leaching from plant residue may diminish with time.

Leaching of nutrients out of the plant material exposed to rainfall in no-till may also contribute to differences observed between the no-till and chisel-till treatments for inorganic N content in solution (Schreiber, 1985; Schreiber and McDowell, 1985). Plant residue averaged 2.43 g N kg^{-1} of plant material. A large portion of the inorganic N in runoff from our no-till treatment could be attributed to native N regardless of the fertilizer N application method used, including the spoke wheel applicator in no-till. While the spoke wheel treatment had higher levels of total inorganic N content in solution compared to the chisel-till treatments, no significant difference was detected in fertilizer N content between this treatment and any of the chisel-till treatments.

For the dry run, there was no significant differences observed for tillage treatment or fertilizer N application method for any of the components measured. This may have been a result of variability of initial soil water when rainfall with the dry run. However, while not significant, runoff solutions tended to have the same results observed in the wet run, with a probability (*P*) of greater F value of $P \leq 0.16$, $P \leq 0.19$, $P \leq 0.23$, and $P \leq 0.21$ for PO_4-P, NO_3-N, NH_4-N, and fertilizer N content in solution, respectively. It was speculated that substantial amounts of fertilizer could be lost from the production system with the first rainfall following application of fertilizer, especially if it occurred shortly following application. However, there was no substantial difference between the levels of either total N or fertilizer N that was lost between the dry and wet runs of the rainfall simulation, with an average over all treatments of 1.42 kg total N ha^{-1} and 0.43 kg fertilizer N ha^{-1} lost during the runoff event. This indicates that under normal fertilizer application conditions in this soil, the initial infiltration rate, as described by Potter et al. (1995) was sufficient to move the UAN fertilizer below the soil surface before runoff is initiated.

Total Nutrient Losses From Site

No significant differences were observed for total N losses or total fertilizer N losses in runoff during the dry run. During the dry run, chisel-till had higher total P losses than no-till. Similar results were observed for total P losses during the wet soil water condition runoff event, with P losses of 0.07 and 0.35 kg P ha^{-1} for no-till compared to 0.75 and 1.1 kg P ha^{-1} for chisel-till from the dry and wet soil water conditions, respectively. While no-till resulted in greater PO_4-P losses in runoff solution, chisel-till resulted in greater total P losses because of greater sediment P losses compared to no-till.

During the wet run, a significant interaction between fertilizer N application method and tillage system for total N lost and total fertilizer N lost was observed (table 4). Total N was higher for the simulated surface band within the no-till tillage system compared to the other treatments, and for the simulated surface band and the simulated coulter-nozzle in no-till compared to chisel-till. Likewise, fertilizer N lost was greater with surface banded and coulter-nozzle application treatments within no-till compared to the other treatments. This increase in fertilizer N losses with the surface band and coulter-nozzle within the no-till was responsible for the increase in total N losses, since no significant difference in native N losses was observed. However, losses were relatively low compared to the fertilizer application rate with only 2% of applied fertilizer being lost during the runoff event.

Summary

No-till reduced total sediment loss during the dry and wet runoff events compared to the chisel-till. Along with

Table 4. Influence of tillage system and fertilizer N application method on total N and total fertilizer N lost in runoff for wet run*

Tillage	Surface Banded	Coulter-Nozzle	Spoke Wheel	Mean
	N (kg ha^{-1})			
Total N				
No-tillage	6.06	5.12	2.62	4.60 a
Chisel-tillage	2.32	2.36	2.30	2.33 a
Mean	4.19 a	3.74 a	2.46 b	
$LSD_{0.10}$ (any two means)	= 2.61			
Total Fertilizer N				
No-tillage	2.94	2.41	0.69	2.01 a
Chisel-tillage	0.17	0.02	0.13	0.11 b
Mean	1.56 a	1.22 a	0.41 b	
$LSD_{0.10}$ (any two means)	= 1.11			

* Values represent means of four replicates. Values followed by the same letter do not differ significantly (0.10 level).

reduced sediment load, total P, total N, and total fertilizer N loss with sediment was reduced with the no-till compared to chisel-till. However, the no-till system increased PO_4-P, total inorganic N, and fertilizer N loss in runoff solution compared to chisel-till. Total P losses in runoff were higher with the chisel-till system compared to no-till. Within the no-till system, fertilizer N application method resulted in increased total N loss and fertilizer N loss with the surface banded and the coulter-nozzle fertilizer N application method. Differences were from increased level of fertilizer N lost due to the application method. However, nutrient losses were low, which would verify that differences between tillage and fertilizer application treatments would not likely be of agronomic importance. In addition, because only 2% of the applied N fertilizer was lost, even with a worse case scenario, this data indicates that the use of UAN in this soil would not likely have any substantial environmental impact regardless of the application method used.

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