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NUTRIENT TRANSPORT IN RUNOFF AS AFFECTED BY DIET, TILLAGE, AND MANURE APPLICATION RATE

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ABSTRACT. *Feedlot operators may increase profitability by including distillers grains in finishing diets. However, the nutrients remaining in the by-product are concentrated by about a factor of three during the distillation process. Manure can be applied to meet single- or multiple-year crop nutrient requirements. The water quality effects of the use of distillers grains in feedlot diets and multiple-year manure application have not been well quantified. The objectives of this study were to (1) compare the runoff water quality effects resulting from the application of manure derived from corn and distillers grain diets, (2) examine the effects of till and no-till conditions on runoff nutrient transport, and (3) compare the water quality impacts of 1-, 2-, and 4-year phosphorus (P) based manure application rates. Simulated rainfall events were applied to 0.75 m wide × 2 m long plots soon after manure application. No significant difference in dissolved phosphorus (DP) or total P (TP) load was found between the corn and distillers grain treatments. The runoff load of TP was significantly larger on the no-till plots than on the till plots. The amount of particulate phosphorus (PP), DP, and TP transported in runoff was significantly affected by multi-year application of manure. The TN content of runoff was similar for till and no-till conditions on the plots containing manure obtained from the distillers grain diet. The environmental effects of the use of manure from a distillers grain diet and multiple-year manure application should be considered when developing nutrient management plans.*

Keywords. *Beef cattle, Feedlots, Manure management, Manure runoff, Nitrogen movement, Nutrient losses, Phosphorus, Runoff, Water quality, Water quality management.*

Distillers by-products can serve as valuable sources of protein and energy for beef cattle (Klopfenstein et al., 2007). Research has shown that feedlots may increase profitability by including distillers grains in finishing diets (Vander Pol et al., 2005). However, the nutrient composition of manure changes when distillers grains are used in feedlot diets.

The starch contained in corn is converted to alcohol and carbon dioxide when corn is fermented to produce alcohol. Since corn is about two-thirds starch, the nutrients remaining in the fermented corn by-product are concentrated about three times (Aines et al., 1997). Wet distillers grains are usually added to corn-based rations in feedlots at rates ranging from 10% to 40% of total ration dry matter. Cattle readily consume wet distillers grains, and the quality and yield grades of carcasses are similar to those fed corn-based diets (Klopfenstein et al., 2007). Inclusion of distillers grains in diets results in greater manure P concentration and P water solubility of manure (Bremer et al., 2007b). The water solubility of P in feedlot manure is an indicator of the potential for P transport in runoff (Bremer et al., 2007a).

The incorporation of manure following land application helps to conserve nutrients and reduce odors. Tillage following the addition of beef cattle manure to cropland areas containing sorghum or wheat residue was found to significantly reduce DP concentrations in runoff (Eghball and Gilley, 1999). The amount of crop residue on the soil surface may also be reduced following tillage. However, crop residues may not significantly affect nutrient concentrations in runoff occurring soon after manure application (Nicolaisen et al., 2007).

Nutrient content near the soil surface influences the concentration of nutrients in runoff (Sharpley et al., 1996). Greater soil nutrient values have been found to increase runoff nutrient concentrations (Pote et al., 1999; Andraski and Bundy, 2003). Nutrient concentrations of runoff have been found to decline during the year following manure addition (Gilley et al., 2007).

Applying manure to meet crop nitrogen (N) requirements results in the addition of phosphorus (P) in excess of crop requirements. The long-term application of surplus P to agricultural soils will result in the accumulation of surplus soil P. Large residual soil test P has been shown to cause excessive P loads in runoff that may result in water quality degradation (Gilley et al., 2008a).

Use of P-based rather than N-based manure application guidelines would reduce the amount of manure applied per unit area. However, a larger total area would be required to meet land application requirements. In addition, it may be

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necessary to apply supplemental inorganic N to meet crop nutrient requirements if P-based land application guidelines were adopted.

Land application areas receive manure each year in a 1-year nutrient-based land application program. Labor, equipment, and land application costs can be reduced if manure is applied to meet multiple-year crop nutrient requirements (Bremer et al., 2007b). However, the water quality effects of multiple-year manure application have not been well quantified.

The objectives of this study were to (1) compare the runoff water quality effects resulting from the application of manure derived from corn and distillers grain diets; (2) examine the effects of till and no-till conditions on runoff nutrient transport; and (3) compare the water quality impacts of 1-, 2-, and 4-year P based manure application rates.

Materials and Methods

Study Site Characteristics

Field tests were conducted in May and June 2009 at the University of Nebraska Roger's Memorial Farm located 18 km east of Lincoln, Nebraska, in Lancaster County. The Aksarben (formerly Sharpsburg) silty clay loam soil (fine, smectitic, mesic Typic Argiudoll) at the site contained 11% sand, 54% silt, and 35% clay, and 18.5 g kg^{-1} of organic C in the top 15 cm of the soil profile. The soil developed in loess under prairie vegetation and had a mean slope of 12%. The site had been cropped using a grain sorghum (*Sorghum bicolor* (L.) Moench), soybean (*Glycine max* (L.) Merr.), winter wheat (*Triticum aestivum* L. cv. Pastiche) rotation, under a no-till management system, and was planted to sorghum during the 2008 cropping season. Herbicide was applied as needed to prevent weed growth.

Experimental Design

Thirty-six plots were established across the slope using the plot design shown in figure 1. Each of the experimental treatments, which included type of manure (derived from a corn or distillers grain diet), tillage (till or no-till), and manure application rate (1-, 2-, and 4-year P-based application for corn (*Zea mays*)), were replicated three times. The experimental tests were done separately by tillage block over a six-week period.

The tillage variable included in the experimental design resulted in 18 till plots and 18 no-till plots. Soil may be transported from its original location as part of the disking operation. Therefore, manure was applied prior to disking on the tillage plots to an area larger than the final plot dimensions to provide more uniform manure incorporation over the experimental area.

A 5 m tandem disc was used to aggressively incorporate manure to a depth of approximately 8 cm. Disking (single pass) occurred up and down the slope in the direction of overland flow. This condition provided a greater runoff and soil loss potential than would have occurred if tillage had occurred along the contour. Tests were conducted on six plots each week. Either a no-till or till condition was randomly selected for all of the plots on which tests were performed each week.

Plot Preparation

Beef cattle manure was collected from 30 m wide × 60 m long feedlot pens located at the U.S. Meat Animal Research Center near Clay Center, Nebraska. Calves born during the spring of 2008 were placed in the pens in September 2008 at a rate of 36 head per pen (50 m^2 per head). Cattle in two of the pens where manure was obtained were fed a corn-based diet. Wet distillers grain was fed in place of corn (40% on a dry matter basis) to the cattle in two immediately adjoining pens. Manure collected from the corn-based and distillers grain pens was placed in different colored buckets to prevent cross-contamination of manures among pens.

Manure characteristics, including total nitrogen (Bremner and Mulvaney, 1982), phosphorus (Olsen and Sommers, 1982), and water content (Gardner, 1986), were measured each week (table 1). The manure that was applied was obtained from the feedlot just prior to field application. The average water content of the manure from the corn-based and wet distillers grain diets were 27% and 25%, respectively (table 1).

Mean application rates of N and P are presented in table 2. Manure and fertilizer application rates were based on annual N and P removal by corn (151 kg N ha^{-1} and 25.8 kg P ha^{-1} for an expected yield of 9.4 Mg ha^{-1}). When calculating manure application rates, it was assumed that N and P availability from beef cattle feedlot manure was 40% and 85%, respectively (Eghball et al., 2002). Supplemental urea ($(NH_2)_2CO$) fertilizer N (39-0-0, N-P-K) was added at rates required to meet annual crop growth requirements.

Soil samples for study site characterization were obtained from the 0 to 2 cm depth on each plot just prior to manure application and were air dried following collection. Mean measured concentrations of Bray and Kurtz No. 1 P (Bray and Kurtz 1945), water-soluble P (Murphy and Riley 1962), NO_3-N, and NH_4-N (measured with a flow injection analyzer using spectrophotometry: Lachat system from Zellweger Analytics, Milwaukee, Wisc.) were 93, 7.9, 12, and 9 mg kg^{-1}, respectively. The soil at the study site had a mean EC value of 0.53 dS m^{-1} and a pH of 7.2.

Rainfall Simulation Procedures

Water used in the rainfall simulation tests was obtained from an irrigation well. Reported nutrient values represent the difference between runoff measurements and concentrations in the irrigation well water. Measured mean concentrations of DP, TP, NO_3-N, NH_4-N, TN, Ca, and Mg in the irrigation water were: 0.19, 0.19, 14.5, 0.04, 14.9, 81, and 22mg L^{-1}, respectively. The irrigation water had a mean EC value of 0.81 dS m^{-1} and a pH of 7.6.

The rainfall simulation procedures adopted by the National Phosphorus Research Project were employed in this study (Sharpley and Kleinman, 2003). A portable rainfall simulator based on the design by Humphry et al. (2002) was used to apply rainfall to 0.75 m wide × 2 m long paired plots. The distance between paired plots was approximately 5 m to accommodate the tandem disk used for tillage. The simulator was used to apply rainfall for 30 min at an intensity of 70 mm h^{-1}. Two additional rainfall simulation tests were conducted for the same duration and intensity at approximately 24 h intervals.

Two rain gauges were placed along the outer edge of each plot, and one rain gauge was located between the plots. Water

Figure 1. Schematic showing the plot layout, till and no-till treatments, and the application rates of manure derived from cattle fed a corn or distillers grain diet.

Table 1. Characteristics of the manure derived from the corn and distillers grain diets (values in parentheses are standard deviations).

Diet	NO_3N[a] (g kg^{-1})	NH_4-N (g kg^{-1})	Total N (g kg^{-1})	Total P (g kg^{-1})	Water Content (g kg^{-1})	EC[b] (dS m^{-1})	pH
Corn	0.01 (0.005)	0.36 (0.08)	25 (2.8)	6.3 (0.70)	270 (127)	29 (4.0)	8.2 (0.51)
Distillers Grain	0.01 (0.004)	0.58 (0.12)	23 (1.1)	7.7 (0.39)	252 (123)	27 (3.0)	7.8 (0.22)

[a] Nutrient concentration was determined on a dry basis.
[b] EC = electrical conductivity; EC and pH were determined in 1:5 manure: water ratio.

Table 2. Application rates for manure derived from the corn and distillers grain diets.

Diet	P Application Interval[a] (years)	Manure Application (Mg ha^{-1})	Total Manure N (kg ha^{-1})	Total Fertilizer N (kg ha^{-1})	Total Manure P (kg ha^{-1})
Corn	1	4.8	48.0	103.0	25.8
	2	9.6	96.0	55.0	51.6
	4	19.2	192.0	0.0	103.2
Distillers grain	1	3.9	35.9	115.1	25.8
	2	7.8	71.8	79.2	51.6
	4	15.6	143.6	7.4	103.2

[a] Manure was applied at a rate required to meet a 1-, 2-, and 4-year corn P requirement.

was first added to the plots with a hose until runoff began to provide more uniform antecedent soil water conditions. A large rubber mat with numerous holes was placed across the soil surface before the addition of water to allow more uniform distribution and to protect the soil surface from scouring.

Plot borders channeled runoff into a sheet metal lip that emptied into a collection trough located across the bottom of each plot. The trough diverted runoff into plastic buckets. A sump pump was then used to transfer runoff into larger plastic storage containers. The storage containers were weighed at the completion of each run to determine total runoff volume. Accumulated runoff was agitated to maintain suspension of solids. A runoff sample was collected for water quality analysis, and an additional sample was obtained for sediment analysis.

Centrifuged and filtered runoff samples were analyzed for DP (dissolved reactive phosphorus) (Murphy and Riley, 1962), and NO_3-N and NH_4-N using a Lachat system (Zellweger Analytics, Milwaukee, Wisc.). Non-centrifuged samples were analyzed for TP (Johnson and Ulrich, 1959), TN (Tate, 1994), pH, and EC. The samples obtained for sediment analysis were dried in an oven at 105°C and then weighed to determine sediment content.

Statistical Analyses

The effects of varying diet, tillage, and manure application rate on runoff nutrient load were determined using ANOVA (SAS, 2003). For a given plot, water quality measurements obtained from each of the three-rainfall simulation runs were included in the analyses and were treated as repeated measures. By using ANOVA, it was possible to test for significant differences among experimental variables. If a significant difference was identified, the least significant difference test (LSD) was used to identify differences among experimental treatments. A probability level < 0.05 was considered significant.

Results and Discussion

Phosphorus Measurements

The TP content of manure from the corn and distillers grain diets was 6.3 and 7.7 g kg^{-1}, respectively (table 1). Since the TP content of manure was larger for the distillers grain diet, less manure must be applied per unit area to meet crop P requirements. As a result, a larger total land application area is required for manure obtained from a distillers grain diet. Since the application rate of TP for a given application interval was identical for both diets (table 2), no significant difference in the export of DP and TP in runoff was found between the corn and distillers grain diets (table 3).

The DP load in runoff from the no-till plots (0.46 kg ha^{-1}) was over twice as large as from the tilled plots (0.22 kg ha^{-1}), but the difference was not statistically significant (table 3). The relatively large standard error of 0.067 for the DP load measurements influenced the lack of significance between the tillage treatments.

The PP load of 0.19 kg ha^{-1} from the plots where manure from the corn diet was applied was significantly greater than the 0.11 kg ha^{-1} measured from the plots containing manure from the distillers grain diet (table 3). The total P content of manure from the corn diet was less than the distillers grain diet (table 1); therefore, a larger quantity of manure from the corn diet was applied (table 2). The increased quantity of manure added on treatments where manure obtained from the corn diet was applied may have resulted in the larger PP load shown in figure 2.

The 0.64 kg ha^{-1} of TP transported in runoff from the no-till plots was significantly greater than the 0.34 kg ha^{-1} measured from the tilled treatments (table 3). Applying manure without incorporation allows surface runoff to interact with larger quantities of manure. As a result, greater amounts of TP were transported in runoff from the no-till than the till treatments.

Larger quantities of nutrients are available for export by overland flow when greater amounts of manure are applied. As a result, PP, DP, and TP loads increased consistently as manure application became larger (table 3). Applying manure to meet a 2-year P crop growth requirement resulted in significant increases in DP and TP load compared to a 1-year

Table 3. Runoff water quality parameters as affected by diet, tillage, and manure application rate.[a]

	DP (kg ha-1)	PP (kg ha-1)	TP (kg ha-1)	NO3-N (kg ha-1)	TN (kg ha-1)	NH4-N (kg ha-1)	EC (dS m-1)	PH	Runoff (mm)	Soil Loss (Mg ha-1)
Diet										
Corn	0.29	0.19	0.48	0.57	3.36	0.49	1.00	7.84	19	0.27
Distillers grain	0.39	0.11	0.48	0.72	3.46	0.83	0.98	7.86	17	0.26
LSD0.05[b]		0.05		0.12		0.17				
Tillage										
Till	0.22	0.11	0.34	0.93	2.91	0.69	0.91	7.81	19	0.28
No-till	0.46	0.19	0.64	0.36	3.91	0.62	1.08	7.89	16	0.24
LSD0.05			0.17	0.39	0.77					
Manure application rate[c]										
1	0.16	0.10	0.26	0.76	3.79	0.57	0.87	7.84	19	0.27
2	0.37	0.13	0.50	0.63	3.58	0.72	0.97	7.88	19	0.27
4	0.48	0.22	0.70	0.54	2.86	0.68	1.14	7.83	16	0.25
LSD0.05	0.12	0.06	0.14	0.15			0.07			
ANOVA										
Diet	0.14	0.01	0.91	0.02	0.80	0.01	0.31	0.58	0.36	0.85
Tillage	0.07	0.19	0.02	0.04	0.02	0.56	0.06	0.06	0.35	0.41
Rate	0.01	0.01	0.01	0.02	0.15	0.39	0.01	0.24	0.12	0.90
Diet × tillage	0.93	0.06	0.51	0.02	0.02	0.01	0.17	0.79	0.05	0.13
Diet × rate	0.79	0.49	0.95	0.24	0.42	0.75	0.28	0.30	0.97	0.99
Tillage × rate	0.10	0.07	0.07	0.06	0.89	0.19	0.01	0.75	0.80	0.56
Diet × tillage × rate	0.93	0.73	0.90	0.22	0.34	0.86	0.69	0.87	0.35	0.69

[a] Reported nutrient values represent the difference between runoff measurements and concentrations in the irrigation well water.
[b] The difference between two sample averages that would be exceeded only 1 in 20 times under simple random sampling from a specified population of differences. No value is listed where significant differences do not exist.
[c] Beef cattle manure was applied to meet 1-, 2-, and 4-year P crop growth requirements for corn.

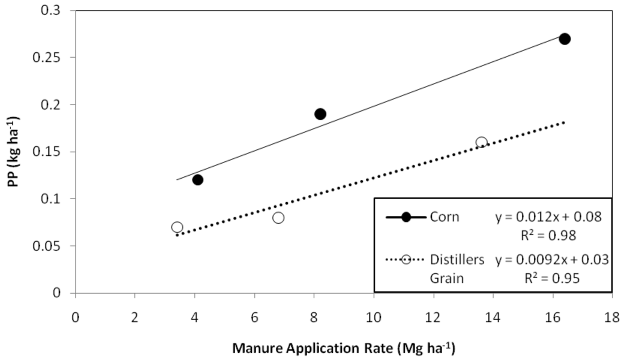

Figure 2. Export of particulate phosphorus (PP) in runoff as affected by manure application rate for the corn and distillers grain diets.

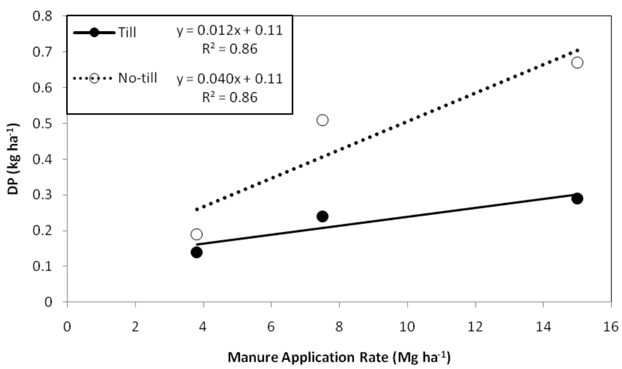

Figure 3. Export of dissolved phosphorus (DP) in runoff as affected by manure application rate.

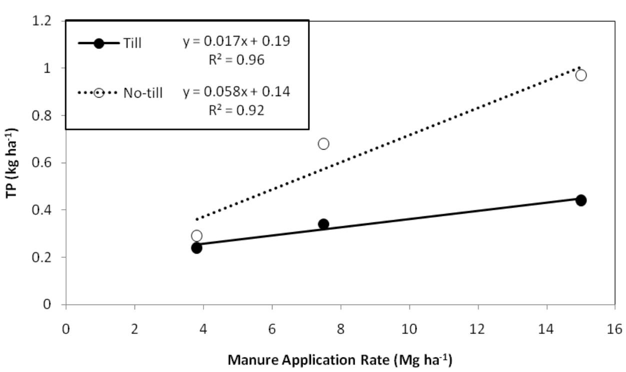

Figure 4. Export of total phosphorus (TP) in runoff as affected by manure application rate for till and no-till conditions.

application requirement. The export of TP in runoff was significantly greater for a 4-year P crop growth requirement than a 2-year application rate.

Regression equations relating PP, DP, and TP loads to manure application rate are presented in figures 2, 3, and 4, respectively. The transport of DP and TP in runoff increased in a linear fashion with manure application rate under both no-till and till conditions (figs. 3 and 4, respectively). Runoff transport of PP also increased in a linear fashion with application rate for manure obtained from both the corn and distillers grain diets (fig. 2).

It is evident from figures 3 and 4 that the incorporation of manure by tillage substantially reduced the amount of P transported in runoff. This fact should not be interpreted from a management perspective as justification for the application of manure in excess of crop nutrient requirements. If excessive residual manure is contained in the soil during subsequent manure application and incorporation, then manure that was buried within the soil profile could be brought to the surface, resulting in increased runoff nutrient transport. The repeated application of excessive amounts of nutrients contained in manure under either till or no-till conditions may result in water quality degradation.

Gilley et al. (2007) measured nutrient concentrations of runoff during the year following the application of beef cattle manure at a rate required to meet annual corn N requirements. The TP concentration of runoff was significantly greater under no-till than till conditions, which was the same result obtained in the present study. Gilley et al. (2008b) also measured nutrient concentrations of runoff from plots containing varying amounts of corn residue on which beef cattle manure was applied to meet annual corn N requirements. Concentrations of TP in runoff were found to be significantly greater under no-till than till conditions, which was also true in this investigation.

Approximately 25% of the TP in beef cattle manure is organic P (Eghball et al., 2002). A more uniform release of inorganic P is expected over time under till conditions since P in manure is readily attached to soil particles. The P content near the surface of soils that were disked following application of compost or fertilizer remained elevated after four years of corn production following the last application of beef cattle compost (Gilley and Eghball, 2002).

Nitrogen Measurements

Crop N needs may not be met when manure is applied at rates necessary to meet P requirements. Therefore, supplemental fertilizer N was added as needed, and the amount of fertilizer N that was applied decreased as manure application rate became larger (table 2).

The fertilizer N is assumed to have been hydrolyzed quickly and to have been readily transported by overland flow. The use of supplemental fertilizer N can be expected to significantly influence runoff N transport. The N transport measurements obtained in this investigation occurred soon after fertilizer addition and should therefore be considered a nutrient transport extreme.

The amount of NO_3-N contained in manure from the feedlot pens where both corn and distillers grain were used was 0.01 g kg^{-1} (table 1). In comparison, the amount of residual NO_3-N contained in the soil at the land application site was 0.012 g kg^{-1}. Runoff NO_3-N loads were significantly larger under till than no-till conditions (fig. 5). The residual N contained in the soil may have resulted in the larger NO_3-N runoff loads on the tilled plots. A significant diet × tillage interaction was measured for NO_3-N (table 3). The reason for the increased transport of NO_3-N in runoff on the tilled plots where manure from the distillers grain diet was applied is not known.

A significant diet × tillage interaction was also measured for NH_4-N (table 3). The NH_4-N content of manure from the distillers grain diet was 0.58 g kg^{-1}, compared to 0.36 g kg^{-1} for the corn diet (table 1). In addition, larger amounts of fertilizer N were added on the distillers grain treatments than the corn treatments (table 1). Therefore, the NH_4-N load from the plots containing manure from the distillers grain diet was greater than that measured from the corn diet, especially under tilled conditions (table 3 and fig. 6).

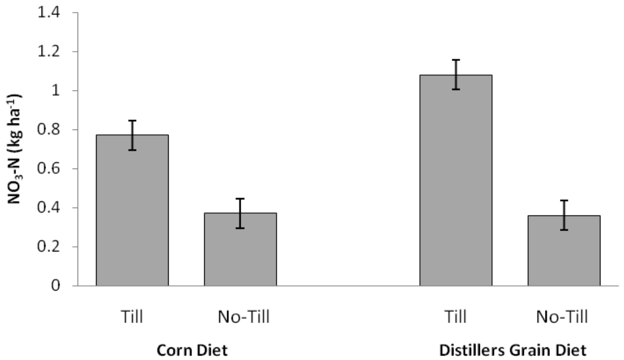

Figure 5. Export of NO_3-N in runoff as affected by tillage for the corn and distillers grain diets. Nutrient transport values were averaged across manure application rates. Vertical bars are standard errors.

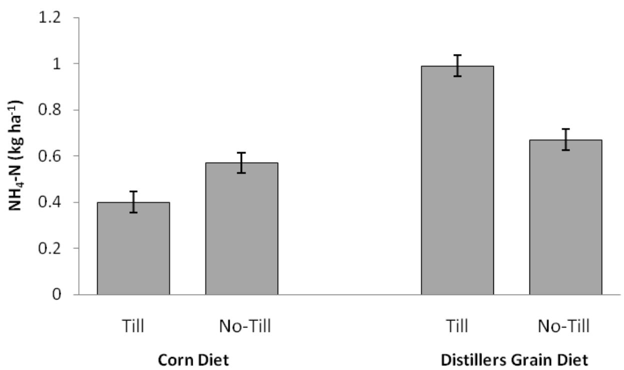

Figure 6. Export of NH_4-N in runoff as affected by tillage for the corn and distillers grain diets. Nutrient transport values were averaged across manure application rates. Vertical bars are standard errors.

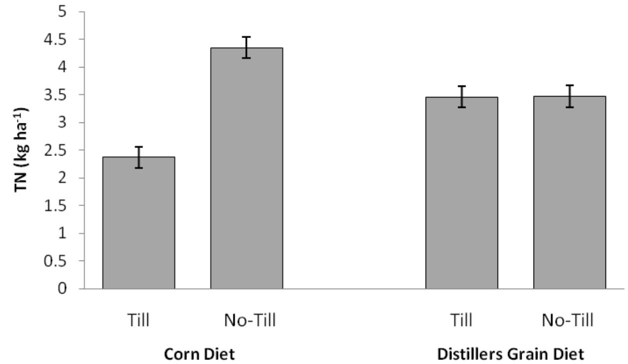

Figure 7. Export of total nitrogen (TN) in runoff as affected by tillage for the corn and distillers grain diets. Nutrient transport values were averaged across manure application rates. Vertical bars are standard errors.

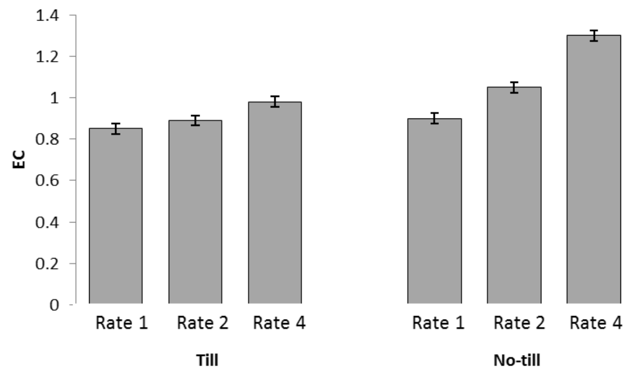

Figure 8. EC of runoff as affected by manure application rate for till and no-till conditions. EC values were averaged across manure application rates. Vertical bars are standard errors.

The amount of TN contained in manure from the corn diet was 25 g kg^{-1}, which was larger than the 23 g kg^{-1} measured for the distillers grain diet (table 1). Therefore, slightly larger amounts of fertilizer N were added on the distillers grain treatments than the corn treatments (table 2). A significant diet × tillage interaction was found for TN (table 3). The TN runoff load for the no-till plots on which the corn-derived manure was applied was significantly greater than the TN load measured on the till plots (fig. 7). The reason for this difference is not known. In comparison, the TN load of runoff was similar for till and no-till conditions on the plots containing manure obtained from the distillers grain diet. Manure application rate did not significantly affect the runoff load of TN (table 3).

Mineralization of organic nutrients in manure is influenced by the composition of the manure and soil characteristics, including the pattern of drying and wetting cycles, temperature, and water content (Cabrera et al., 2005). It has been estimated that the organic N in cattle manure mineralized the first year after application is 30%, while the TN available is 40% (Eghball, 2000). Concentrations of NO_3-N in cattle manure are usually low, but manure N can be transformed to NO_3-N through oxidation of NH_4-N after land application through nitrification (Reynolds, 2006). This study was conducted to measure nutrient transport in runoff occurring soon after manure application. Additional tests are needed to identify the effects of mineralization of organic nutrients in manure on runoff nutrient transport.

Measurements of EC, pH, Runoff, and Soil Loss

The EC of the manure from the corn and distillers grain diets at the time of application was 29 and 27 dS m^{-1}, respectively (table 1). Manure may contain high levels of soluble salts that may be detrimental to crop growth if applied at large enough rates (Reynolds, 2006). The EC of runoff consistently increased as manure application rates increased on both the till and no-till treatments (fig. 8). For a given manure application rate, EC values were greater under no-till then till conditions.

At the time of application, the pH of the manure from the corn and distillers grain diets was 8.2 and 7.8, respectively (table 1). Calcium carbonate ($CaCO_3$) is commonly added to cattle diets as a source of calcium, and much of the $CaCO_3$ is excreted in manure. Diet, tillage, and manure application rate did not significantly affect pH measurements of runoff (table 3).

The mean quantity of runoff occurring during the experimental tests was 18 mm (table 3). The quantity of runoff was not significantly affected by diet, tillage, or manure application rate. Reported nutrient load information was calculated as the product of runoff volume and nutrient concentration. Nutrient concentration values for the various experimental treatments shown in table 3 can be determined from the runoff load values (plot area was 1.5 m^2).

The runoff values shown in table 3 can also be used to calculate the rainfall to runoff ratio (approximately 35 mm of rainfall was applied during each rainfall simulation run). The rainfall to runoff ratio has been used to predict the transport of DP in runoff from land application areas (Vadas et al., 2004, 2005) and in the development of a phosphorus loss quantification tool for estimating phosphorus loss in runoff from manure and fertilizer (Vadas et al., 2009).

The mean soil loss value for the experimental tests was 0.27 Mg ha^{-1}. Soil loss measurements were not significantly affected by diet, tillage, or manure application rate (table 3). The experimental tests on the tilled treatments were conducted soon after the test plots, which had been maintained in a no-till condition, were disked. Soil erodibility on the recently tilled treatments would be expected to increase substantially over time.

Conclusions

The amount of TP that was applied in manure was the same for both diets. As a result, no significant difference in the transport of DP and TP was found between the corn and distillers grain treatments. Applying manure without incorporation allows surface runoff to interact with larger quantities of manure. Therefore, a significantly greater amount of TP was transported in runoff from the no-till than the till treatments. Larger quantities of nutrients are also available for transport by overland flow when greater amounts of manure are applied. As a result, the amount of PP, DP, and TP exported in runoff was significantly affected by manure application rate.

Significantly larger NO_3-N loads were measured in runoff under till than no-till conditions. The NH_4-N content of manure from the distillers grain diet was 0.58 g kg^{-1} compared to 0.36 g kg^{-1} for the corn diet. Therefore, the NH_4-N runoff load from the plots containing manure from the distillers grain diet was greater than from the corn diet. The amount of TN contained in manure from the corn diet was 25 g kg^{-1}, which was similar to the 23 g kg^{-1} measured for the distillers grain diet. The TN content of runoff was similar for till and no-till conditions on the plots containing manure obtained from the distillers grain diet.

The EC of runoff consistently increased as manure application rated increased on both the till and no-till treatments. For a given manure application rate, EC values were greater under no-till than till conditions. At the time of application, the pH of manure from the distillers grain and corn diets was 7.8 and 8.2, respectively. Diet, tillage, and manure application rate did not significantly affect pH measurements of runoff.

The mean runoff and soil loss values for the experimental tests were 18 mm and 0.27 Mg ha^{-1}, respectively. Diet, tillage, and manure application rate did not significantly affect runoff and erosion measurements.

The use of distillers grains and multiple-year application of manure can provide substantial economic benefits to feedlot operators. However, the environmental effects of varying diet and manure application rate should be considered when developing nutrient management plans.

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