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# Effects of Narrow Grass Hedges on Nutrient Transport From Land Application Areas

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# Effects of Narrow Grass Hedges on Nutrient Transport From Land Application Areas

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***Abstract****. The placement of stiff-stemmed grass hedges on the contour along a hill slope has been shown to decrease runoff nutrient transport. This study was conducted to measure the effectiveness of a narrow grass hedge in reducing runoff nutrient transport from plots with a range of soil nutrient values. Composted beef cattle manure was applied at dry weights of 0, 68, 105, 142, and 178 Mg $ha^{-1}$ to a silty clay loam soil and then incorporated by disking. Soil samples were collected 243 days later for analysis of water-soluble phosphorus (WSP), Bray and Kurtz No.1 phosphorus (Bray-1 P), $NO_3$-N and $NH_4$-N. Three 30-min simulated rainfall events, separated by 24-hour intervals, were then applied. The transport of dissolved phosphorus (DP), total P (TP), $NO_3$-N, $NH_4$-N, total nitrogen (TN), runoff, and soil erosion were measured from 0.75 m wide x 4.0 m long plots. Compost application rate was found to significantly affect WSP, Bray-1 P, and $NO_3$-N content of the soil. The transport of DP, TP, $NO_3$-N, $NH_4$-N, TN, runoff and soil erosion was reduced significantly on the plots with a grass hedge. Mean runoff on the hedge and no-hedge treatments was 17 and 29 mm, respectively, and soil erosion rates were 0.12 and 1.48 Mg $ha^{-1}$. Compost application rate significantly affected the transport of DP, TP, and $NO_3$-N in runoff. The experimental results indicate that stiff-stemmed grass hedges, planted at selected down slope intervals, can significantly reduce the transport of nutrients in runoff from areas with a range of soil nutrient values.*

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**Keywords.** Grass filters, Land application, Manure management, Manure runoff, Nitrogen movement, Nutrient losses, Phosphorus, Runoff, Sediment detention, Water quality

# Introduction

The use of stiff-stemmed grass hedges (barriers) has been shown to effectively reduce soil loss from cropland areas (Kemper et al., 1992). Improved soil hydraulic properties beneath stiff-stemmed grass hedge systems may also reduce the quantity of runoff (Rachman et al., 2004a and 2004b). Narrow grass hedges promote sediment deposition and berm formation, and diffuse and spread overland flow (Dabney et al., 1995). The potential for concentrated flow is reduced since stiff-stemmed grass hedges are usually planted along the contour at relatively short intervals that allow multiple passes of farm implements (Meyer et al., 1995). As a result, much of the sediment carried by overland flow moves only a short distance before it is deposited.

Stiff-stemmed grass hedges significantly reduced runoff and soil loss from cotton plots in Mississippi (McGregor et al., 1999; Cullum et al., 2007). Under no-till conditions, plots in southwest Iowa with corn residue and stiff-stemmed hedges averaged 52% less runoff and 57% less soil loss than comparable plots without grass hedges (Gilley et al., 2000). Under tilled conditions, the plots with corn residue and grass hedges averaged 22% less runoff and 57% less soil loss than comparable plots without grass hedges.

The enhanced infiltration within stiff-stemmed grass hedge systems helps to reduce runoff nutrient loads. Sediment containing adsorbed nutrients may be deposited in the ponds formed immediately above grass hedges. Owino et al. (2006) found that nutrient runoff losses from a clay loam soil in Kenya were also significantly reduced by stiff-stemmed grass hedges.

Stiff-stemmed grass hedges effectively decreased nutrient losses in runoff following manure and fertilizer application on a cropland site in Iowa (Eghball et al., 2000). A single narrow grass hedge reduced runoff concentrations of dissolved P (DP) by 47%, bioavailable P (BAP) by 48%, particulate P (PP) by 38%, total P (TP) by 40%, and $NH_4$-N by 60% during the wet simulation run on no-till plots receiving manure, compared to similar plots without hedges. On the disked plots with a grass hedge, concentrations of DP, BAP, PP, TP, and $NH_4$-N in runoff decreased by 21, 29, 43, 38, and 52%, respectively.

Narrow grass hedges have also been used in combination with vegetative filter strips (Blanco-Canqui et al., 2004a). When placed immediately above vegetative filter strips, stiff-stemmed grass hedges minimized soil and nutrient losses resulting from interrill and concentrated flow (Blanco-Canqui et al., 2004b and 2006).

Manure has been used effectively for crop production and soil improvement because it contains nutrients and organic matter (Eghball and Power, 1994). Runoff and soil loss values are reduced substantially on sites receiving long-term manure application (Gilley and Risse, 2000). As manure application rates increased, runoff and soil loss rates decreased. However, an increase in soil nutrient content can result in greater nutrient concentrations of runoff (Gilley et al., 2007a).

When rainfall occurs soon after manure application, soil nutrient values may not significantly impact runoff nutrient concentrations (Eghball et al., 2002b). Gilley et al. (2007b) examined the effect of time following the application of manure on nutrient transport by runoff. The objective of this study was to measure the effectiveness of a narrow grass hedge in reducing runoff nutrient transport from plots containing a range of soil nutrient values.

# MATERIALS AND METHODS

## SITE CHARACTERISTICS

This field study was conducted at the University of Nebraska Rogers Memorial Farm located 18 km east of Lincoln, NE. The soil at the site developed in loess under prairie vegetation and had a mean slope of 5%. The Sharpsburg silty clay loam soil (fine, smectitic, mesic Typic Argiudoll) contained 11% sand, 54% silt, and 35% clay (Kettler et al., 2001), and 18.5 g $kg^{-1}$ of organic C in the top 15 cm of the soil profile. This soil is moderately well drained and permeability is moderately slow.

The study 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 long-term continuous no-till management system with controlled wheel traffic. The study area was planted to soybean during the 2002 - cropping season. Soil on the site was undisturbed following soybean harvest. Herbicide (glyphosate) was applied as needed to control weed growth.

Soil samples for study site characterization were obtained on July 7, 2003 at soil sampling depths of 0 – 5 and 5 – 15 cm. For each depth increment, soil samples were collected at existing soil water conditions from several locations on each plot and composited. The plot area immediately above the grass hedge was used to collect soil samples on the hedge treatments.

Following collection, soil samples were transported to the lab, clods were broken by hand and the samples were air-dried. The dried samples were ground prior to analyses. The Murphy and Riley (1962) procedure, which involved shaking 2 g of soil for 5 min in 20 ml of deionized water, was used to determine water-soluble phosphorus (WSP). As an index of P availability, the Bray-1 P procedure (Bray and Kurtz, 1945) provides a relative estimate of P concentration in the soil solution that limits the growth of plants.

Soil $NO_3$-N and $NH_4$-N concentrations (extracted using a 2 M KCl solution) were measured with a flow injection analyzer using a spectrophotometer (Lachat system from Zellweger Analytics, Milwaukee, WI) (Stevenson 1982). The mean content of WSP, Bray-1 P, $NO_3$-N, and $NH_4$-N in the 0 – 5 cm soil sampling depth of the hedge and no-hedge treatments was 2.1, 30, 12.4 and 5.6 mg $kg^{-1}$, respectively. Electrical conductivity and pH (Klute 1994), measured in a 1:1 soil / water ratio, were 0.69 dS $m^{-1}$ and 6.88.

## PLOT PREPARATION

Thirty 0.75 m wide by 4 m long plots were established with the longer plot dimension parallel to the slope in the direction of overland flow. Experimental treatments included the presence or absence of a switch grass (Panicum virgatum) hedge, compost application rate, and inflow rate. The existence or absence of a grass hedge was the main plot treatment and compost application rate was the subplot treatment.

The switch grass hedges were established in 1998 in parallel rows following the contour of the land. A specialized grass drill was used in the seeding operation. The grass hedges were spaced at intervals along the hill slope to allow multiple passes of tillage equipment. The hedges were part of a strip-cropping system and row crops were planted between the hedge strips.

A 1.4 m wide grass hedge established near the bottom of the hillslope was examined in this study. The grass hedge was located at the down slope portion of 15 of the plots (established using a randomized design) whose slope gradients varied from 4.5 to 5.2%. The other 15 plots (also established using a randomized design) were located immediately below the grass hedge and had slope gradients ranging from 4.4 to 6.1%.

The composted beef cattle manure applied to the study site was obtained from the University of Nebraska – Agricultural Research and Development Center near Ithaca. Concentrations of $NO_3$-N, $NH_4$-N, TN, and TP in the composted beef cattle manure, determined on a dry weight basis, were 1.22, 0.41, 9.45 and 5.32 g $kg^{-1}$, respectively. Electrical conductivity and pH, measured in a 1:5 compost/water ratio, were 17.2 dS $m^{-1}$ and 7.2.

Compost was applied by hand on November 7, 2002 at rates of 0, 68, 105, 142, and 178 Mg $ha^{-1}$ (dry weight) using 19 L buckets. These rates were determined from previous mineralization studies conducted to identify the effects of compost application rate on soil P content (Eghball and Power, 1999; Eghball, 2000; Eghball and Barbarick, 2002; Eghball et al., 2002b). Each of the five compost application rates was replicated three times.

To meet the estimated N requirement to achieve a target corn yield of 9.4 Mg $ha^{-1}$, compost would have been applied at a dry rate of 48 Mg $ha^{-1}$, assuming 40% N availability during the first year following manure application (Eghball and Power, 1999). The equivalent dry rates of total N that were added were 0, 0.62, 0.96, 1.30, and 1.63 Mg $ha^{-1}$, while total P was applied at equivalent dry rates of 0, 0.36, 0.56, 0.76, and 0.95 Mg $ha^{-1}$.

Soil may be transported from its original location during tillage. Therefore, the composted manure was applied to an area larger than the final plot dimensions to allow for tillage-induced translocation. Following compost application, the study area was disked to an 8-cm depth across the slope perpendicular to the direction of overland flow. No additional tillage occurred during the study.

## RAINFALL SIMULATION PROCEDURES

Water used in the rainfall simulation tests was obtained from an irrigation well. Measured mean concentrations of DP, TP, $NO_3$-N, $NH_4$-N, and TN in the irrigation water were: 0.21, 0.21, 16.8, 0.03 and 16.8 mg $L^{-1}$, respectively. The irrigation water had a mean EC value of 0.69 dS $m^{-1}$ and a pH of 7.27. Nutrient contents reported below are the difference between the nutrients in runoff and those in the irrigation water.

Field rainfall simulation tests were conducted from July 14 to August 8, 2003 using a portable rainfall simulator based on the design by Humphry et al. (2002). The simulator provides continuous flow from a single nozzle at an intensity of approximately 70 mm $h^{-1}$ to a pair of 0.75 m wide by 2 m long plots. Experimental procedures established by the National Phosphorus Research Project (NPRP) (Sharpley and Kleinman, 2003) were employed in this study. Two rain gauges were placed along the outer edge of each plot, and one rain gauge was located between the plots.

A single layer of burlap material was placed on the plots to reduce surface disturbance during the pre-wetting process. To provide more uniform antecedent soil water conditions among treatments, water was first added to the plots with a hose until runoff began. The quantity of water required to initiate runoff varied among individual plots depending upon antecedent soil water contents.

The simulator was used to apply rainfall for 30-min. Plots were covered with tarps to prevent the input of natural rainfall after the initial rainfall event. Two additional rainfall simulation tests were conducted for the same duration and intensity at approximately 24-hr intervals.

Sheet metal borders located at the top and sides of the plots channeled runoff into a sheet metal lip and collection trough. The trough extended across the bottom of each plot and diverted runoff into aluminum washtubs. After each rainfall simulation event, the washtubs were weighed to determine the total mass of runoff plus sediment. Average runoff rate during the third simulation run was 1.50 kg $min^{-1}$. Accumulated runoff was then agitated to suspend the eroded soil. Two separate runoff samples were collected for water quality analyses and two additional runoff samples were obtained for sediment analyses.

After the first 30 minutes of the third simulation run, runoff was diverted into a flume where a stage recorder was mounted to measure discharge rate. Inflow was then applied at the top of each plot in four successive increments to produce average runoff rates of 4.65, 9.07, 13.23 and 17.20 kg $min^{-1}$. Rainfall continued during the inflow tests. Mean runoff rates were measured once steady-state conditions had become established as indicated by the stage recorder. Using runoff measurements without the addition of rainfall as a reference, simulated plot lengths were approximately 3.1, 6.0, 8.8, and 11.5 m.

A narrow mat made of green synthetic material often used as an outdoor carpet was placed on the soil surface beneath the inflow device. The mat helped to prevent scouring and distributed flow more uniformly across the plot. Flow addition for each inflow increment occurred only after steady state runoff conditions for the previous inflow increment had become established and samples for nutrient and sediment analyses had been collected. Steady state runoff conditions were determined using the stage recorder and flume. Each inflow increment was maintained for approximately eight minutes.

Runoff samples were first filtered and then centrifuged before being analyzed for DP (Murphy and Riley, 1962), $NO_3$-N, and $NH_4$-N using a Lachat system (Zellweger Analytics, Milwaukee WI). Non-centrifuged samples were analyzed for TP (Johnson and Ulrich, 1959) and TN (Tate, 1994). The samples obtained for sediment analysis were dried in an oven at 105°C and then weighed to determine sediment content.

## STATISTICAL ANALYSES

Three separate analysis of variance (ANOVA) (SAS Institute, 2003) were performed to determine the effects of a) soil sampling depth, grass hedge, and compost application rate on soil characteristics, b) grass hedge and compost application rate on runoff nutrient load, and c) grass hedge, compost application rate, and inflow rate on nutrient transport in runoff. In determining runoff nutrient load, measurements of DP, TP, $NO_3$-N, $NH_4$-N, and TN from the three-rainfall simulation runs were averaged. A probability level $< 0.05$ was considered significant.

# RESULTS AND DISCUSSION

## SOIL CHARACTERISTICS

The soil depth x hedge x compost rate interaction was significant for WSP ($P = 0.01$), Bray-1 P ($P = 0.03$), and $NO_3$-N ($P = 0.03$) (table 1). All 2-way interactions were significant for WSP and Bray-1 P. The hedge x soil depth interaction was significant for $NH_4$-N ($P = 0.01$).

### *Soil Phosphorus*

Significant differences in WSP and Bray-1 P content were found between the 0 - 5 and 5 - 15 cm soil sampling depths on the hedge and no-hedge treatments where compost was added (table 1). The addition of compost did not significantly affect WSP and Bray-1 P values obtained at the 5 – 15 cm soil sampling depth on the hedge and no-hedge treatments.

**Table 1. Effects of soil depth, hedge, and compost rate on water-soluble P (WSP), Bray and Kurtz No. 1 phosphorous (Bray-1 P), $NO_3$-N and $NH_4$-N content of the soil.**

| | | | Variable | | | |
|---|---|---|---|---|---|---|
| Soil Depth (cm) | Hedge | Compost Rate (Mg $ha^{-1}$) | WSP (mg $kg^{-1}$) | Bray-1 P (mg $kg^{-1}$) | $NO_3$-N (mg $kg^{-1}$) | $NH_4$-N (mg $kg^{-1}$) |
| 0-5 | Hedge | 0 | 1.3 | 22 | 14.5 | 2.6 |
| | | 68 | 9.2 | 91 | 18.2 | 3.4 |
| | | 105 | 21.0 | 173 | 25.9 | 2.9 |
| | | 142 | 19.4 | 169 | 44.2 | 2.9 |
| | | 178 | 26.7 | 231 | 32.1 | 2.5 |
| | No-Hedge | 0 | 2.8 | 37 | 10.2 | 8.5 |
| | | 68 | 22.2 | 256 | 28.8 | 10.2 |
| | | 105 | 17.2 | 177 | 27.6 | 7.6 |
| | | 142 | 37.0 | 272 | 28.5 | 7.2 |
| | | 178 | 44.8 | 385 | 32.5 | 10.4 |
| 5-15 | Hedge | 0 | 0.8 | 3 | 7.0 | 2.8 |
| | | 68 | 1.2 | 4 | 15.3 | 2.9 |
| | | 105 | 1.0 | 5 | 20.7 | 3.0 |
| | | 142 | 1.0 | 8 | 22.0 | 2.1 |
| | | 178 | 0.9 | 12 | 22.1 | 2.6 |
| | No-Hedge | 0 | 0.9 | 4 | 4.2 | 4.1 |
| | | 68 | 1.3 | 10 | 14.0 | 3.6 |
| | | 105 | 0.7 | 6 | 16.8 | 3.7 |
| | | 142 | 0.7 | 7 | 25.1 | 4.7 |
| | | 178 | 1.5 | 20 | 23.1 | 3.8 |
| $LSD_{0.05}$ | | | 5.7 | 56 | 8.9 | 2.5 |
| ANOVA | | | --------------------------Pr>F-------------------------- | | | |
| | Soil depth | | 0.01 | 0.01 | 0.01 | 0.01 |
| | Hedge | | 0.01 | 0.01 | 0.44 | 0.01 |
| | Compost rate | | 0.01 | 0.01 | 0.01 | 0.65 |
| | Soil depth x hedge | | 0.01 | 0.01 | 0.83 | 0.01 |
| | Soil depth x compost rate | | 0.01 | 0.01 | 0.70 | 0.45 |
| | Hedge x compost rate | | 0.01 | 0.02 | 0.18 | 0.68 |
| | Soil depth x hedge x compost rate | | 0.01 | 0.03 | 0.03 | 0.29 |

Compost application rate influenced WSP and Bray-1 P measurements at the 0 – 5 cm soil sampling depth on both the hedge and no-hedge treatments. However, soil test P values did not consistently increase with each incremental compost application. Differences in soil test P measurements among compost application rates are influenced by the non-uniform nature of the compost material and varying mineralization rates.

For a particular compost application rate, significant differences were found between WSP and Bray-1 P measurements obtained on the hedge and no-hedge treatments at the 0 – 5 cm soil sampling depth. As an example, application of compost at a rate of 178 Mg $ha^{-1}$ resulted in a mean Bray-1 P value on the hedge treatment of 231. In comparison, addition of the same amount of compost on the no-hedge treatment resulted in a mean Bray-1 P value of 385.

Previous deposition of sediment may have increased the silt and clay sized soil fractions above the hedge. As a result, nutrient adsorption rates may have been substantially different on the plot areas located above and below the grass hedge. Stiff-stemmed grass hedges have also been shown to influence soil macroporosity (Rachman et al., 2005).

The following regression equation ($R^2 = 0.92$), obtained from data collected on the no-hedge plots at the 0 - 5 cm soil sampling depth, relates WSP to Bray-1 P measurements:

$$\text{WSP} = 0.119 \text{ Bray-1 P} - 1.93 \qquad (1)$$

Equation 1 was derived using WSP values ranging from 1 to 49 mg $kg^{-1}$ and Bray-1 P measurements varying from 26 to 407 mg $kg^{-1}$.

### ***Soil Nitrogen***

No differences in soil $NO_3$-N content were found between the hedge and no-hedge treatments (table 1). Compost application rate and soil depth significantly affected soil $NO_3$-N values. Significant differences in soil $NO_3$-N content were found among selected compost application rates at both the 0 – 5 and 5 – 15 cm soil sampling depths.

Compost application rate did not significantly affect soil $NH_4$-N content. Soil $NH_4$-N content at the 0 – 5 cm soil sampling depth was significantly greater on the no-hedge than the hedge treatments. No significant differences in soil $NH_4$-N content were found between the 0 – 5 and 5 – 15 cm soil sampling depth increments on the hedge treatments. However, soil $NH_4$-N content was significantly greater at the 0 – 5 cm soil sampling depth on the no-hedge treatments. The deposition of sediment with different chemical and physical characteristics above the hedge is thought to have been responsible for the smaller soil $NH_4$-N values found on the hedge treatments.

## RUNOFF CHARACTERISTICS

The hedge x compost rate interaction was significant for DP ($P = 0.01$) and TP ($P = 0.04$) (table 2).

### ***Runoff Phosphorus***

No significant differences in DP loss were found among compost application rates on the hedge treatment (table 2). However, compost application rate significantly affected the transport of DP in runoff for the no-hedge treatment and runoff transport of DP consistently increased as compost application rate became greater (fig. 1). Runoff loss of DP was less on the hedge than the no-hedge treatments for each of the compost application rates.

Runoff transport of TP varied from 0.10 to 0.30 kg $ha^{-1}$ on the hedge treatment and 0.28 to 0.87 kg $ha^{-1}$ on the no-hedge treatment. The 1.4 m wide narrow grass hedges covered approximately 35% of the 4 m long plot area. As a result, nutrient transport would be expected to be less on the hedge treatments because of the smaller upslope contributing area.

Regression equations were developed relating runoff transport of DP to Bray-1 P content of the soil at the 0 – 5 cm soil sampling depth (fig. 2). The range of Bray-1 P values was less on the hedge than the no-hedge treatments. The grass hedge was especially effective in reducing the transport of DP in runoff from sites with larger soil test P values.

It is recognized that the $R^2$ value presented in fig. 2 for the no-hedge condition is relatively small. The line representing the regression equation for the hedge condition was included to allow comparisons in DP transport with the no-hedge treatment. It is not recommended that the regression equation presented for the hedge condition be used for predictive purposes.

An increase in compost application rate did not always result in consistently greater nutrient transport values. The compost used in the tests was by nature non-homogeneous and would, therefore, be expected to have varying mineralization rates. As a result, the physical and chemical characteristics of the compost applied to individual plots and nutrient transport potential may have been different.

**Table 2. Effects of hedge and compost rate on the transport of dissolved P (DP), $NO_3$-N, $NH_4$-N, total N (TN), runoff, and erosion averaged over the three rainfall simulation runs.**

| Hedge | Compost Rate ($Mg\ ha^{-1}$) | DP ($kg\ ha^{-1}$) | TP ($kg\ ha^{-1}$) | $NO_3$-N ($kg\ ha^{-1}$) | $NH_4$-N ($kg\ ha^{-1}$) | TN ($kg\ ha^{-1}$) | Runoff (mm) | Erosion ($Mg\ ha^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| Hedge | | | | | | | | |
| | 0 | 0.05 | 0.10 | 0.01 | 0.00 | 3.63 | 18 | 0.12 |
| | 68 | 0.08 | 0.15 | 0.13 | 0.00 | 4.12 | 18 | 0.13 |
| | 105 | 0.09 | 0.19 | 0.17 | 0.00 | 4.39 | 18 | 0.13 |
| | 142 | 0.18 | 0.30 | 0.56 | 0.00 | 4.72 | 18 | 0.12 |
| | 178 | 0.09 | 0.15 | 0.15 | 0.00 | 3.14 | 14 | 0.10 |
| No-Hedge | | | | | | | | |
| | 0 | 0.06 | 0.28 | 0.26 | 0.01 | 7.35 | 29 | 2.01 |
| | 68 | 0.15 | 0.40 | 0.28 | 0.01 | 6.34 | 25 | 1.30 |
| | 105 | 0.24 | 0.70 | 0.65 | 0.01 | 8.26 | 30 | 1.68 |
| | 142 | 0.33 | 0.54 | 0.88 | 0.01 | 7.54 | 28 | 1.41 |
| | 178 | 0.48 | 0.87 | 1.04 | 0.01 | 8.61 | 31 | 0.90 |
| $LSD_{0.05}$ | | 0.14 | 0.38 | 0.71 | 0.01 | 2.59 | 8 | 0.64 |
| ANOVA | | ----------------------------------------------- | | | Pr>F | | | ----------------------------------------------- |
| Hedge | | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Compost rate | | 0.01 | 0.01 | 0.01 | 0.64 | 0.63 | 0.89 | 0.18 |
| Hedge x compost rate | | 0.01 | 0.04 | 0.17 | 0.28 | 0.32 | 0.55 | 0.20 |

### *Runoff Nitrogen*

Both hedge and compost application rate significantly affected runoff loss of $NO_3$-N (table 2). When averaged across compost rates, 0.20 kg $NO_3$-N $ha^{-1}$ was measured in runoff from the hedge treatment compared to 0.62 kg $ha^{-1}$ from the no-hedge treatment. The presence of a grass hedges also reduced the transport of TN in runoff. An average of 4.00 kg TN $ha^{-1}$ was measured in runoff from the hedge treatment compared to 7.62 kg $ha^{-1}$ for the plots without a hedge.

### *Runoff and Soil Erosion Measurements*

Runoff and soil erosion were not influenced by compost application rate (table 2). When averaged across compost treatments, runoff was significantly less on the hedge than the no-hedge treatments, averaging 17 and 29 mm, respectively. Soil erosion on the hedge treatments varied from 0.10 to 0.13 Mg $ha^{-1}$ compared to 0.90 to 2.01 Mg $ha^{-1}$ on the no-hedge treatments. Gilley et al. (2000) found that plots with corn residue and grass hedges averaged 22% less runoff and 57% less soil loss under tilled conditions than comparable plots without grass hedges.

## RUNOFF CHARACTERISTICS AS AFFECTED BY INFLOW

The hedge x compost rate x inflow rate interaction was significant for TP ($P = 0.02$) and $NO_3$-N ($P = 0.01$) (table 3). Significant hedge x compost rate interactions were found for $NO_3$-N ($P = 0.01$) and $NH_4$-N ($P = 0.01$). The hedge x inflow rate interaction was significant for all of the runoff characteristics except $NH_4$-N ($P = 0.20$). Significant compost rate x inflow rate interactions were found for DP ($P = 0.01$), TP ($P = 0.01$), and $NO_3$-N ($P = 0.01$).

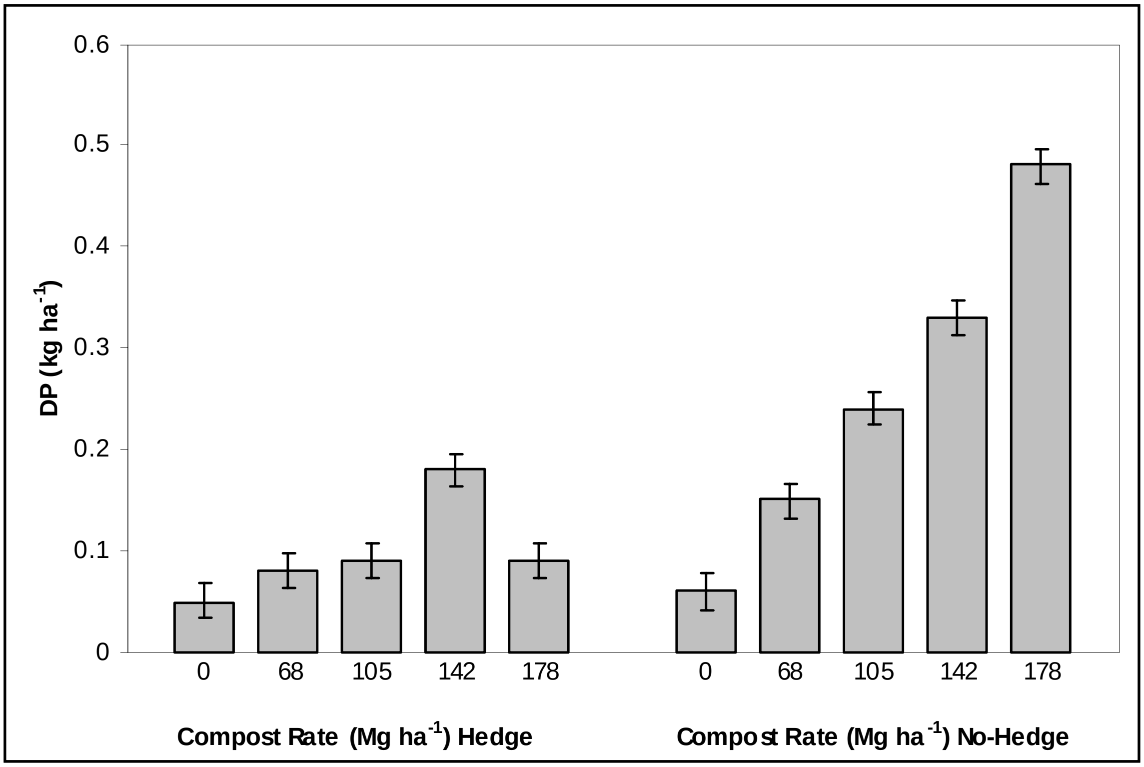

**Figure 1. Transport of dissolved phosphorus (DP) in runoff as affected by compost application rate for the hedge and no-hedge condition. Nutrient transport values are averages from three rainfall simulation runs. Vertical bars are standard errors.**

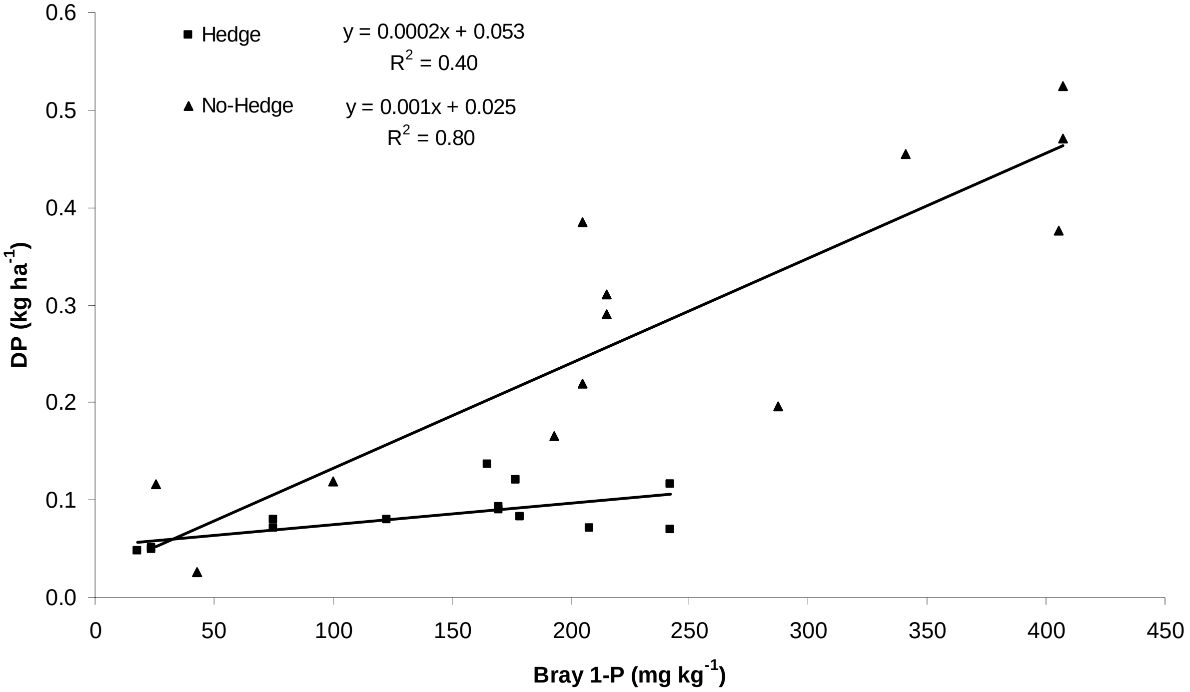

**Figure 2. Transport of dissolved phosphorus (DP) in runoff as affected by Bray-1 P content of soil for the hedge and no-hedge condition**.

### ***Phosphorus Measurements***

The mean transport rate of DP was less for the hedge than the no-hedge treatments, averaging 6.4 and 18.9 g ha$^{-1}$ min$^{-1}$, respectively (table 3). Average TP measurements of 10.3 and 47.3 g ha$^{-1}$ min$^{-1}$ were found for the hedge and no-hedge treatments. Differences in nutrient transport rates for DP and TP occurred among compost application rates (table 3).

As inflow rate became greater, nutrient transport rates for DP and TP consistently increased. The transport of DP and TP in runoff varied from 3.6 to 22.5 g ha$^{-1}$ min$^{-1}$ and 8.7 to 52.8 g ha$^{-1}$ min$^{-1}$, respectively**.**

**Table 3. Runoff water quality parameters and soil loss as affected by hedge, compost rate, and inflow rate.**

| Variable | DP | TP | $NO_3$-N | $NH_4$-N | Total N | Soil Loss |
|---|---|---|---|---|---|---|
| | (g ha$^{-1}$ min$^{-1}$) | (g ha$^{-1}$ min$^{-1}$) | (g ha$^{-1}$ min$^{-1}$) | (g ha$^{-1}$ min$^{-1}$) | (g ha$^{-1}$ min$^{-1}$) | (kg ha$^{-1}$ min$^{-1}$) |
| <u>Hedge</u> | | | | | | |
| Hedge | 6.4 | 10.3 | 23.6 | 0.15 | 579 | 14.1 |
| No-Hedge | 18.9 | 47.3 | 49.2 | 0.71 | 840 | 114.6 |
| LSD $_{0.05}$ | 7.2 | 15.4 | 17.0 | 0.24 | 107 | 53.3 |
| <u>Compost Rate (Mg ha$^{-1}$)</u> | | | | | | |
| 0 | 1.7 | 6.9 | 19.1 | 0.34 | 687 | 69.9 |
| 68 | 14.6 | 50.2 | 29.4 | 0.83 | 802 | 97.0 |
| 105 | 9.5 | 18.9 | 15.3 | 0.37 | 669 | 82.2 |
| 142 | 23.7 | 38.4 | 49.3 | 0.34 | 752 | 40.5 |
| 178 | 13.9 | 29.6 | 69.0 | 0.28 | 637 | 32.1 |
| LSD $_{0.05}$ | 11.2 | 24.1 | 26.7 | 0.34 | | |
| <u>Inflow Rate</u> | | | | | | |
| Zero | 3.6 | 8.7 | 2.9 | 0.16 | 171 | 29.0 |
| One | 6.6 | 15.5 | 18.0 | 0.31 | 371 | 24.8 |
| Two | 11.7 | 28.9 | 28.8 | 0.55 | 694 | 46.4 |
| Three | 19.1 | 37.9 | 59.5 | 0.69 | 1023 | 81.1 |
| Four | 22.5 | 52.8 | 73.1 | 0.46 | 1288 | 140.5 |
| LSD $_{0.05}$ | 5.1 | 9.5 | 13.1 | 0.26 | 81 | 54.3 |
| ANOVA | | | | | | |
| Hedge | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Compost rate | 0.02 | 0.02 | 0.01 | 0.03 | 0.35 | 0.54 |
| Inflow rate | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Hedge x compost rate | 0.21 | 0.07 | 0.01 | 0.01 | 0.75 | 0.61 |
| Hedge x inflow rate | 0.01 | 0.01 | 0.01 | 0.20 | 0.02 | 0.01 |
| Compost rate x inflow rate | 0.01 | 0.01 | 0.01 | 0.13 | 0.94 | 0.95 |
| Hedge x compost rate x inflow rate | 0.08 | 0.02 | 0.01 | 0.19 | 0.67 | 0.96 |

### *Nitrogen Measurements*

Mean $NO_3$-N transport rates were less on the hedge than the no-hedge treatments, averaging 23.6 and 49.2 g $ha^{-1}$ $min^{-1}$, respectively (table 3). Mean $NH_4$-N runoff values of 0.15 and 0.71 g $ha^{-1}$ $min^{-1}$ were measured on the hedge and no-hedge treatments, respectively. Differences in transport rates of $NO_3$-N and $NH_4$-N also occurred among compost treatments.

The transport of $NO_3$-N and $NH_4$-N in runoff varied with inflow rate. Runoff transport rates for $NO_3$-N ranged from 2.9 to 73.1 g $ha^{-1}$ $min^{-1}$. In comparison, transport of $NH_4$-N in runoff varied from 0.16 to 0.69 g $ha^{-1}$ $min^{-1}$.

Mean TN transport rate was less on the hedge than the no-hedge treatment, averaging 579 and 840 g $ha^{-1}$ $min^{-1}$, respectively. The transport rate for TN consistently increased as inflow rate became greater. Differences in TN transport rates were found among inflow treatments (fig. 3) with values varying from 171 to 1288 g $ha^{-1}$ $min^{-1}$. Thus, the transport of TN in runoff can be expected to increase with down slope distance.

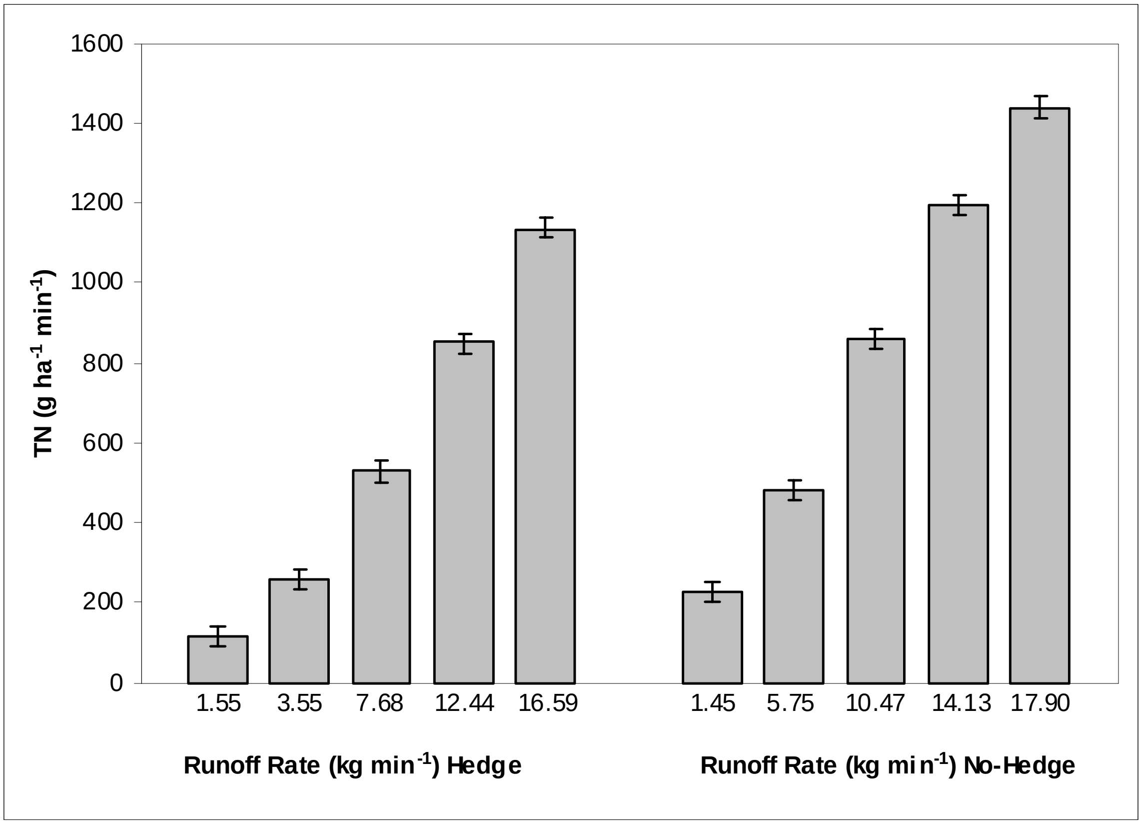

**Figure 3. Transport of total nitrogen (TN) in runoff as affected by runoff rate for the hedge and no-hedge condition. Nutrient transport values were averaged across compost rates. Vertical bars are standard errors.**

### Soil Erosion Measurements

Compost application rate did not affect soil loss rates (table 3). The 14.1 kg $ha^{-1}$ $min^{-1}$ of mean soil loss measured from the hedge treatment was less than the 115 kg $ha^{-1}$ $min^{-1}$ obtained for the no-hedge condition (fig. 4). Differences in soil loss rates were measured among inflow treatments with values varying from 24.8 to 141 kg ha$^{-1}$ min$^{-1}$. The expected increase in soil loss rate with flow rate is well established (Gilley et al., 1987 and 1990).

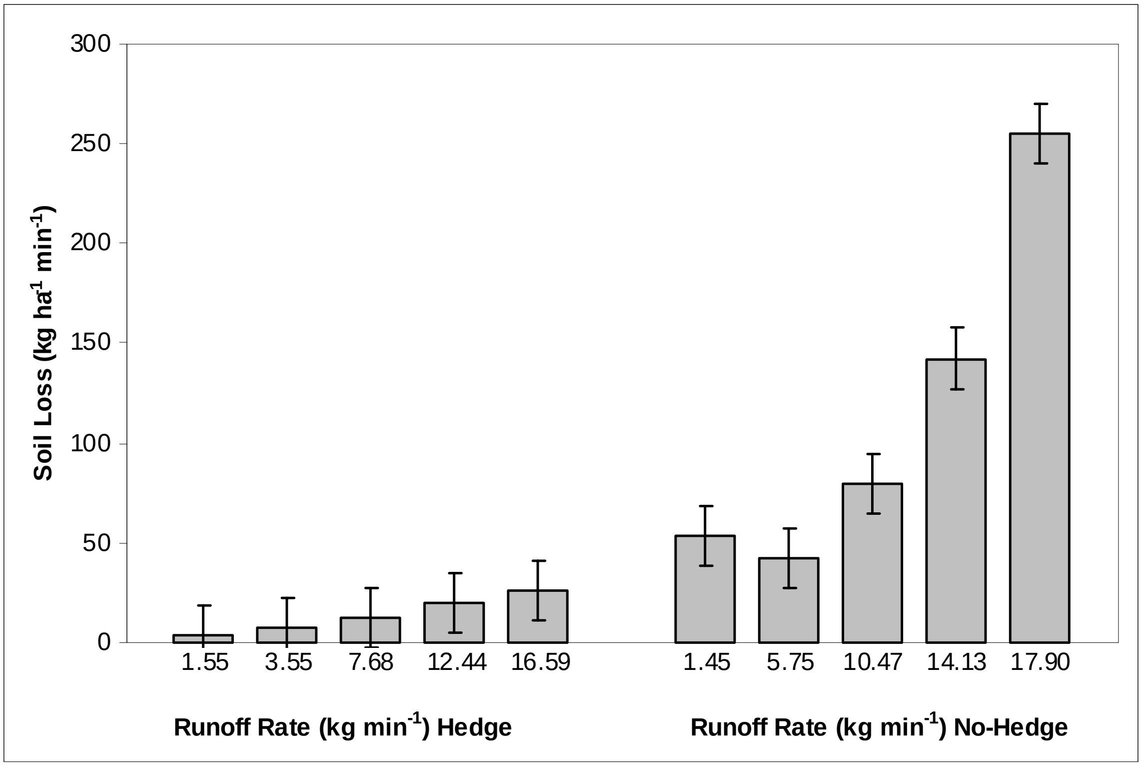

**Figure 4. Soil loss as affected by runoff rate for the hedge and no-hedge condition. Soil loss values were averaged across compost rates. Vertical bars are standard errors.**

## THE USE OF NARROW GRASS HEDGES AS A BEST MANAGEMENT PRACTICE

Previous studies have shown that narrow grass hedges can effectively reduce runoff and soil loss from cropland areas. Results from this investigation suggest that narrow grass hedges can also decrease nutrient transport in runoff from soils containing excessive amounts of nutrients. The greatest reductions in runoff nutrient transport were found on those areas with the largest soil nutrient content.

Manure may be applied to meet annual or multi-year crop nutrient requirements. Land application costs can be reduced if manure is added at less frequent intervals. The use of stiff-stemmed grass hedges planted along the contour may be an effective best management practice on cropland areas that receive multi-year applications of manure.

The effectiveness of a single grass hedge in reducing nutrient transport by overland flow was examined in this study. Several stiff-stemmed grass hedges are usually planted along the contour from near the top to the bottom of the hill slope. Thus, several grass hedges may intercept overland flow as it moves down slope. Our experimental results indicate that nutrient transport increases with flow rate. A single grass hedge was able to effectively decrease nutrient transport in runoff for the flow rates examined in this study.

At present, the mechanisms responsible for reducing runoff nutrient transport have not been clearly identified. The stiff-stemmed grass hedges cause sediment to be deposited immediately above the hedge. The finer textured particles contained in previously deposited sediment may be able to absorb substantial amounts of nutrients. The slope gradients above a grass hedge may also be considerably less, increasing the length of time overland flow is in contact with the soil surface.

The vegetative materials within the grass hedge may also sorb nutrients contained in overland flow. The nutrient sorption capacity of grass hedges has not been identified. Removal of vegetative materials from the grass hedge area following harvest would positively impact nutrient balance within the grass hedge system.

The use of stiff-stemmed grass hedges should be viewed as one of many best management practices for reducing sediment and nutrient transport by overland flow. The presence of a grass hedge system should not be viewed as an opportunity to apply fertilizer or manure at rates in excess of crop nutrient requirements. Stiff-stemmed grass hedges are best used as one part of a suite of soil and water conservation best management practices.

## CONCLUSIONS

Stiff-stemmed grass hedges significantly reduced the transport of DP and TP in runoff. When averaged across compost application rates, the 0.20 kg $NO_3$-N $ha^{-1}$ in runoff from the hedge treatment was significantly less than the 0.62 kg $ha^{-1}$ measured from the no-hedge treatment. The stiff-stemmed grass hedge also decreased TN transport in runoff from 7.62 kg $ha^{-1}$ on the no-hedge treatment to 4.00 kg $ha^{-1}$ on the plots with a grass hedge.

The existence of a grass hedge, compost rate, and inflow rate all significantly influenced transport rates of DP, TP, $NO_3$-N, and $NH_4$-N on the treatments with added inflow. The 14.1 kg $ha^{-1}$ $min^{-1}$ of mean soil loss measured from the hedge treatment was less than the 115 kg $ha^{-1}$ $min^{-1}$ obtained for the no-hedge condition. Differences in soil loss rates were measured among inflow treatments with values varying from 24.8 to 141 kg $ha^{-1}$ $min^{-1}$.

Stiff-stemmed grass hedges appear to be able to significantly reduce the transport of nutrients in runoff from land application areas with a range of soil nutrient values. Runoff nutrient transport will significantly increase as overland flow rates become larger. A stiff-stemmed grass hedge effectively reduced nutrient and soil loss for the varying runoff rates used in this study.

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