PHOSPHORUS LOSSES IN RUNOFF WATER AS AFFECTED BY TILLAGE[1] AND PHOSPHORUS FERTILIZATION

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Abstract

Phosphorus (P) in runoff from cropland can contribute to nutrient enrichment and eutrophication of surface water bodies. Research was continued during 1996 to determine which tillage systems and which methods of applying P fertilizer will result in the least P losses in runoff water for grain sorghum production under somewhat poorly drained soil conditions in east-central Kansas. The tillage systems evaluated were a chisel-disk-field cultivate system, a ridge-till system, and a no-till system. Fertilizer treatments were a P check, 50 lb/a P_2O_5 surface broadcast, and 50 lb/a P_2O_5 deep-banded. Runoff from natural rainfall was collected during three pre- and post-grain sorghum fertilization and planting periods, 1994-1996. Volume of runoff in 1994 was greatest from the chisel-disk system. In 1995, most runoff occurred with no-till. In 1996, runoff was highest with the ridge-till system. Averaged across all runoff events over three years, the volume of runoff was similar for each of the tillage systems, indicating no significant reduction in runoff volume with conservation tillage for this somewhat poorly drained soil. Sediment losses and total P losses in the runoff water followed the pattern chisel-disk > ridge-till > no-till. Soluble P losses were highest with the conservation tillage systems, largely because of surface application of P fertilizer. Losses of soluble P were greatly reduced when the P fertilizer was subsurface-banded. Comparisons of total and soluble P losses with bioavailable P losses showed that most algae available P in the runoff from this location was in the soluble P form. This could be because of limited sediment losses from minimum slope and low soil erosion potential. There were no differences in grain yield in 1994 with tillage or P treatments. In 1995, with late planted grain sorghum, dry weather during grain fill and an early freeze, no-till and deep-banded P fertilizer combinations produced highest yield. As of this writing, the 1996 grain sorghum crop has not yet been harvested.

Introduction

Agricultural runoff from cropland can contribute to the nutrient enrichment in lakes, streams and rivers. High levels of phosphorus in runoff water accelerates eutrophication of surface water bodies, producing water that has undesirable odor and taste for drinking and recreation. Excess phosphorus in runoff is a problem in the Hillsdale lake watershed in east-central Kansas. Farmers in the watershed are being urged to reduce non-point

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sources of phosphorus entering surface water (Big Bull Creek Water Quality Incentive Project). Losses of P from conventional-tilled land are believed to be mainly of P attached to soil with smaller amounts dissolved in the runoff water. Consequently, soil erosion control practices and use of conservation tillage systems are being encouraged. Several recent studies (McDowell and McGregor, 1980; Barisas et al., 1978), however, have indicated that soluble P concentrations and losses increase with conservation tillage systems because of generally shallower fertilizer incorporation and release of P from unincorporated crop residues. This, coupled with the potential for greater than normal runoff with conservation tillage systems, because of an abundance of slowly permeable soils in the watershed, might mitigate some or all of the sediment P reduction benefits associated with conservation tillage. Consequently, we hypothesized that for somewhat poorly drained soils, best P practices may require both soil erosion control measures and subsurface placement of P fertilizer. The deeper fertilizer placement would place the fertilizer P below the critical surface-water soil interface and mixing zone (approximately the top 1 inch of soil). Baker and Laflen (1982) reported that by injecting fertilizer P, increased losses of dissolved and sediment available P were prevented. Deeper P placement might also benefit crop yield because of better positional location for root uptake during dry surface soil conditions.

Procedure

The study was conducted at the East-central Kansas Experiment Field, Ottawa, on a 1.0 to 1.5 % slope, somewhat poorly drained, Woodson silt loam soil (fine, montmorillonitic, thermic, Abruptic Argiaquolls). This site represents prime farmland in the east-central region of Kansas. The study was a randomized complete block split-plot design with tillage systems as whole plots and fertilizer treatments as subplots. All treatments were replicated three times. The tillage systems evaluated were chisel-disk-field cultivate (chisel in the fall, disk in the early spring and field cultivation immediately prior to planting) ridge-till (with ridges formed in the fall), and no-till. These tillage systems were established five years prior to the start of this study. Superimposed over these tillage systems were three P fertilizer treatments, a P check with no P fertilizer applied, 50 lb/a P_2O_5 surface broadcast, and 50 lb/a P_2O_5 deep-banded (coulter-knifed) at approximately 4 inch depth on 15 inch centers. This rate of P application was for two crops, grain sorghum and the following year's soybean crop. Every-other-year grain sorghum soybean rotations are common in the watershed. Bray P-1 soil test P at the start of this study was in the medium to high range. Liquid 7-21-7 fertilizer was the source of P for all P fertilizer applications. Surface broadcast P in the chisel-disk-fleld cultivate system was incorporated with the field cultivation before planting. All runoff data collected was in the sorghum year of the crop rotation on previous year soybean stubble. Runoff from five runoff events in 1994, five runoff event in 1995, and six runoff events in 1996, spanning the period before and after P fertilizer application and grain sorghum planting, were collected. This period is considered most susceptible to erosion and P losses. Runoff water from natural rainfall was collected by delimiting 50 square foot areas (5 ft x 10 ft) with metal frames driven approximately three inches deep into the ground in each

10 x 50 ft plot. The runoff from within these frames was directed to a sump and then pumped though a series of dividers (five spitters) to reduce the volume and to obtain a composite sample. The volume of runoff from the splitter outlet in which the sample container had not run over was collected and measured. This volume, along with the splitter calibration factor for that outlet (which was determine by running a known volume of water through the spitter) was used to determine the total amount of runoff volume. Sediment concentration and losses, total P (perchloric acid digestion of unfiltered runoff samples), and soluble P (filtrate from samples through 45 um filters) concentrations and losses in the runoff water were measured all years. Beginning in 1995, we also analyzed runoff water for bioavailable P (FeO-strip extractable P). This is a relatively new analytical procedure (Sharpley, 1993) which has been correlated with algae useable P. Rainfall amounts and dates in which runoff were collected in 1994 were: 0.70 (5-6-94), 2.05 (6-5-94), 1.30 (7-1-94), 1.60 (7-18-94), and 1.10 inches (8-1-94); in 1995: 0.80 (7-4-95), 1.94 (7-20-95), 1.68 (7-31-95), 0.72 (8-3-95), and 1.10 inches (8-15-95); and in 1996 1.75 (5-26-96), 2.45 (6-06-96), 2.02 (6-16-96), 1.85 (7-04-96), 1.28 (7-08-96), and 2.04 inches (7-22-96). According to long-term rainfall information, rainfall amounts during the 1994 sampling period were 20 % below average, during the 1995 sampling period 20% above average, and during the 1996 sampling period 38% above average. The P fertilizer treatments were applied on 21 June 1994, 11 July 1995, and 21 June 1996. Pioneer 8310 grain sorghum was planted in 1994 and 1995 and Pioneer 8500 grain sorghum in 1996.

Results

For brevity of reporting, all data, except for soluble P data for 1995, will be presented as totals of sampling years, or as averages over period of years.

Runoff volume and soil loss

The amount of surface water that ran off varied with rainfall events, tillage systems, and years. Generally, most runoff occurred with the largest and most intense rainfall events. However, moisture and infiltration differences between tillage systems preceding the rainfall events also influenced runoff amounts. Runoff, (Figure 1) when totaled across all 1994 samplings, and when averaged across all fertilizer treatments, was highest with the chisel-disk and ridge-till systems and lowest with no-till. In 1995, runoff was greatest with no-till and ridge-till and lowest with chisel-disk. This was because of tillage in the chisel-disk system drying and loosing the soil prior to rainfall events which increased infiltration and reduced runoff. In 1996, with above average rainfall, the ridge-till system had the most runoff. These yearly differences in runoff suggest that rainfall timing, intensities, and amounts, as well as differences in infiltration within the tillage systems preceding the rainfall events, interact to affect runoff. When averaged across all sampling years (16 runoff events), the amount of runoff was 18 percent of the total rainfall received for the chisel-disk system, 21 percent for the ridge-till system, and 18 percent for the no-till system, suggesting no significant decrease in runoff volume with conservation tillage

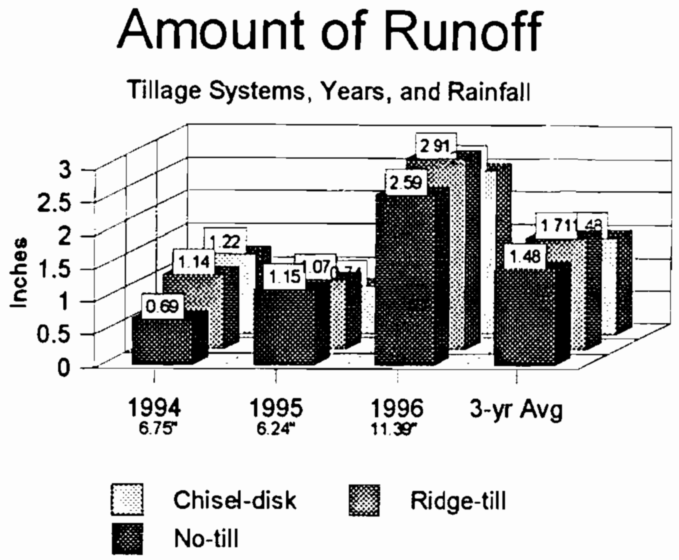

Figure 1. Amount of runoff as influenced by tillage and years.

compared to chisel-disk for this imperfectly drained soil. This differs from runoff reductions of up to 50 percent and more reported with conservation tillage systems by some researchers (Baker, 1987).

Soil losses in the runoff water (Figure 2) generally paralleled runoff amounts, but intensity and timing of individual rainfall events also influenced losses. Soil losses in the runoff water, overall, were greatest in 1996 when rainfall and runoff amounts were highest. Sediment losses generally followed the pattern chisel-disk > ridge-till > no-till suggesting that full-width soil loosing and residue incorporation results in greater soil losses than partial (shaving of the ridge at planting in the ridge-till system) or very limited soil and residue disturbance (coulter at planting in no-till). Averaged across all runoff events and years, soil losses for these pre- and post-plant periods were 0.76 ton/a for the chisel-disk system, 0.48 ton/a for the ridge-till system, and 0.25 ton/a for the no-till system. This is roughly a 40 and 70 percent reduction in soil loss , respectively, for the ridge-till and no-till tillage systems, compared to the chisel-disk system, Although, these amounts are for only a part of the crop year, all are below the T (tolerance) level of 4 ton/a for this soil.

Phosphorus losses

Phosphorus losses were influenced by rainfall events, tillage system, fertilizer practices and years. In 1995 there was a statistically significant interaction (0.05 level) between tillage systems and P fertilization practices on soluble and bioavailable P losses. Consequently, main effects of tillage and fertilizer practices for soluble and bioavailable P losses are presented jointly. Total P losses when summed across all runoff events for 1994 (Figure 3) were highest with the ridge-till and chisel-disk systems, and lowest for no-

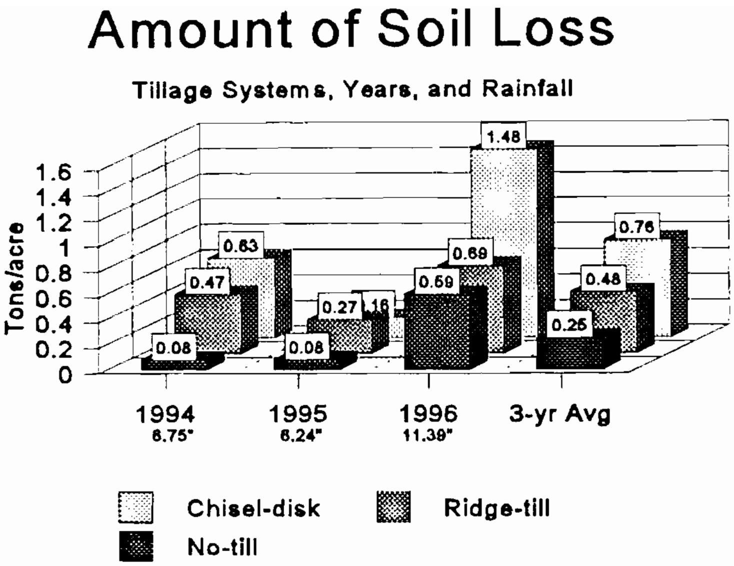

Figure 2. Soil losses as influenced by tillage and years.

till. These differences generally paralleled soil losses. In 1995, losses of total P were reduced and were higher with no-till and ridge-till compared to chisel-disk.. This was because of less runoff volume in the chisel-disk system with resultant less soil and total P loss. Total P losses in 1996 were highest with chisel-disk, intermediate for ridge-till, and lowest for no-till. This corresponds again with the amount of soil loss. The effects of the P fertilizer practices on losses of total P were not statistically significant for any year (data not shown). However, there was some evidence that surface applied P may have been causing some increase in total P losses.

Losses of soluble P were not affected by the tillage and P fertilizer treatments in 1994. In 1995, losses of soluble P varied across tillage systems and interacted with P fertilizer treatments (Table 1). The first runoff after P application In 1994 resulted in only 0.01 inch of runoff, whereas, the first runoff after P application in 1995 produced 0.40 inches of runoff. Also, in 1994 there was 0.03 inches of rain between P application and first runoff. In 1995, there was no measurable rainfall between P application and first runoff. In 1996, two showers occurred between P application and first runoff (0.07 and 0.24 inches) and first runoff produced 0.31 inch of runoff. In 1996, as in 1995, both tillage and P fertilizer treatments caused significant differences in soluble and bioavailable P losses, but there was no significant interaction between tillage systems and fertilizer treatments on P losses in 1996. Soluble P losses averaged across all years and across all runoff events are shown in Figure 4. In the chisel-disk system, where broadcast P was incorporated by field cultivation before planting, there was negligible increased losses of soluble P compared to no P fertilizer application. In the ridge-till system, where the broadcast P fertilizer was applied on the soil surface and was partially covered by the shaving of the ridge at planting, losses of soluble P increased moderately compared to no P fertilizer

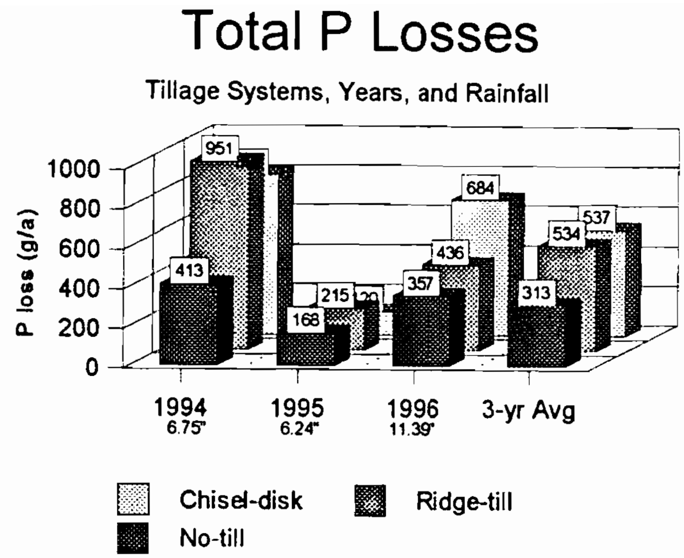

Figure 3. Total P losses as influenced by tillage and years.

Table 1. Soluble P losses in surface water runoff as influenced by tillage and P rate/placement.

		Date of Runoff Water Collection					
		7-4-95	7-20-95	7-31-95	8-3-95	8-15-95	
		Rainfall Amount					
Tillage System	Fertilizer tmt.	0.80"	1.94"	1.68"	0.72"	1.10"	'95 Total
		Soluble P loss, g/a					
Chisel-disk, fld. cult.	P Check	0.0	2.9	2.2	1.4	0.4	6.8
Chisel-disk, fld. cult.	50 lb/a P_2O_5 BC	0.0	3.8	4.5	2.5	0.3	11.0
Chisel-disk, fld. cult.	50 lb/a P_2O_5 KN	0.0	1.7	2.3	0.7	0.3	5.1
Ridge-till	P Check	0.4	8.6	4.0	2.3	0.5	15.8
Ridge-till	50 lb/a P_2O_5 BC	0.7	45.7	10.6	8.7	1.7	67.4
Ridge-till	50 lb/a P_2O_5 KN	0.4	7.5	5.4	2.3	0.7	16.3
No-till	P Check	0.4	9.4	2.7	1.3	0.2	14.0
No-till	50 lb/a P_2O_5 BC	1.0	129.5	20.6	57.6	2.1	210.7
No-till	50 lb/a P_2O_5 KN	0.5	10.7	4.6	3.1	0.4	19.2
L.S.D. 0.05		0.8	33.0	5.1	7.7	1.2	33.9

Fertilizer P applied 7-11-95

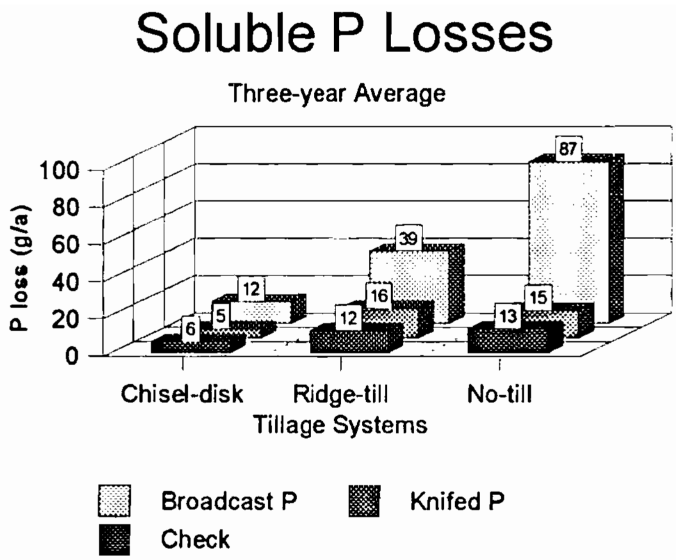

Figure 4. Soluble P losses as influenced by tillage and P rate/placement.

application. In the no-till system, where the broadcast P was nearly all left exposed on the soil surface, soluble P losses increased nearly seven fold compared to no P fertilizer applied. Knifed P, on the other hand, had negligible effects on increased soluble P losses compared to no P application in all tillage systems. The 1995 soluble P data (Table 1) also show that the losses of soluble P in runoff for no-till and ridge-till were highest for broadcast P the first runoff event after P application and diminished with successive runoff events..

Because losses of soluble P and total P in runoff do not exclusively indicate algae useable P, bioavailable P tests for algae useable P in runoff water have been developed. Comparisons of the FeO-strip bioavailable P losses (Figure 5) with total P and soluble P losses (Figures 3 and 4) show a strong relationship with soluble P losses. This suggests that for this soil type and landscape most bioavailable P losses were associated with soluble P losses.

Grain Yield

Grain yield in 1994 was not affected by tillage or the P fertilizer treatments. In 1995, with grain sorghum planting delayed by a wet spring, with dry weather during grain fill, and an early freeze, no-till yield was on the average 4 bu/a better than the other tillage systems and deep-banded P (knifed P) increased yield by 6 bu/a compared to broadcast P (data not shown). The 1996 sorghum crop as of this writing has not yet been harvested.

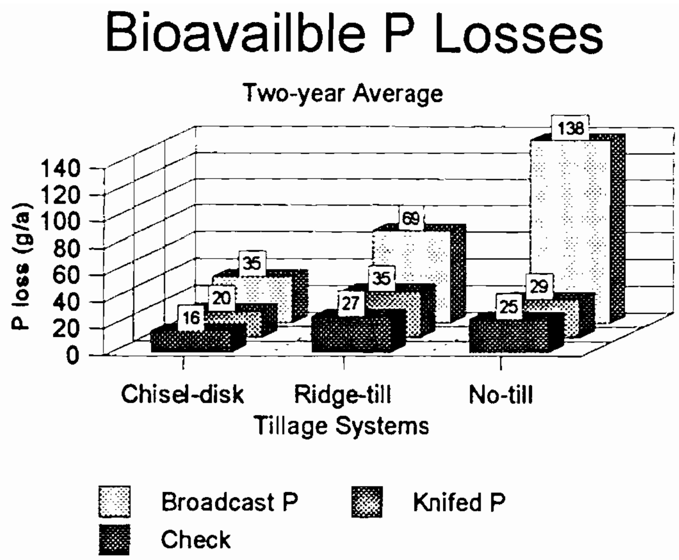

Figure 5. FeO-strip bioavailable P losses as influenced by tillage and P rate/placement.

Conclusions

These data suggest that on minimum slope, imperfectly drained soils, conservation tillage systems, especially no-till, can reduce soil and sediment forms of P losses, but may have quite variable effects on soluble and bioavailable P losses depending on how the P fertilizer is applied. If P fertilizer is broadcast and left on the surface of the soil then there is increased chance for losses of soluble P. If the P fertilizer is subsurface applied then soluble P losses were minimal compared to no P fertilizer application. Our work also suggests that switching from full-width tillage systems like chisel-disk-field cultivate to conservation tillage systems must be accompanied by practices which place P fertilizers below the soil surface or algae useable P (bioavailable P) in runoff may actually increase.

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