2002 Sugarbeet Research and Extension Reports.Volume 33, Page 102-105

THE EFFECT OF TILLAGE AND PHOSPHORUS FERTILIZER PLACEMENT ON PHOSPHORUS RUNOFF FROM SUGAR BEET PRODUCTION SYSTEMS

Matt.D. Ruark
Former MS Student in Department of Soil, Water, and Climate, University of Minnesota, St. Paul, Minnesota now at Department of Agronomy, Purdue University, West Lafayette, Indiana

John.A. Lamb and George.W. Rehm
Department of Soil, Water, and Climate, University of Minnesota, St. Paul, Minnesota

Mark.W. Bredehoeft and Steve R. Roehl
Southern Minnesota Beet Sugar Cooperative, Renville, Minnesota

Abstract

The objective of this study was to determine the differences in the amount of phosphorus (P) in runoff from land under sugar beet production caused by different management practices and phosphorus fertilizer placement. The study was set up as a split plot experimental design, replicated three times. The whole plot treatments were: 1) corn/soybean rotation, with moldboard plow as primary tillage before soybean; 2) corn/soybean rotation, with chisel plow as primary tillage before corn; 3) sugar beet/soybean/corn rotation, with moldboard plow as primary tillage before sugar beet; 4)sugar beet/soybean/corn rotation, with a DMI chisel plow as primary tillage before sugar beet; 5) sugar beet/soybean/corn rotation, with a DMI chisel plow as primary tillage before sugar beet with a spring cover crop of oats. The split plot treatments were broadcast or subsurface band application of phosphorus fertilizer. A rainfall simulator was used to create runoff events at an intensity of 2.2 inches per hour on soybean in whole plot treatment 1, on corn in whole plot treatment 2, and on sugar beet in whole plot treatments 3, 4, and 5. Runoff was collected and analyzed for orthophosphate (DP) and total phosphorus (TP). Runoff flow rate and sediment loss were also measured. Analysis of variance findings concluded no significant differences of DP and TP contents and concentrations among tillage/crop rotation or between P fertilizer placements. Regression analysis was conducted to relate which source, transport, or soil factors were influential in P loss. Six regression models were constructed. Phosphorus concentration models were heavily influenced by soil test phosphorus (STP) levels, while P content losses were influenced by transport factors such as runoff or sediment loss.

Introduction

Environmental concerns over phosphorus (P) management have arisen in the past few decades. Many soils in agricultural production areas have elevated levels of soil test phosphorus (STP). Phosphorus can leave cultivated fields in a dissolved form in runoff (dissolved P, DP) or as an adsorbed form on eroded soil particles (particulate P. PP). Phosphorus can then enter surface water systems and cause accelerated eutrophication in streams, rivers, and lakes. Phosphorus in these surface waters can become long-term as well as short-term sources of nutrients for algae and other biota (Sharpley et al., 1992). The term eutrophication refers to the natural aging of freshwater bodies caused by nutrient enrichment. Since P is generally the limiting nutrient for algae and plant growth in these systems, a population explosion of these organisms is the result of excess P in freshwater (Sharpley et al., 1994). When the algae dies, microorganisms in the water decompose the algae. The microorganisms use the oxygen in the water to facilitate this process, which leads to a state of hypoxia, or fish kill (USEPA, 1996). Water use for recreation, industry, and drinking are also impacted by eutrophication. The United States Environmental Protection Agency (USEPA) has identified eutrophication as the main cause of impaired fresh surface water quality (USEPA, 1996).

Substantial research activity has focused on phosphorus runoff. Phosphorus runoff studies have been conducted with cropping systems that range from corn-soybean rotations in Iowa (Laflen and Tabatabai, 1984) to wheat-fallow rotations in Texas (Sharpley, 1995) to sorghum-soybean rotations in Eastern Kansas (Kimmel et al., 2001). There is little, if any, information of how P in runoff is affected by sugar beet production systems and associated management practices needed for profitable production. The small size of the sugar beet seed and the shallow depth of planting cause sugar beet production fields to have little crop residue from the previous crop at planting. This leaves the field more susceptible to soil erosion and subsequent P losses. An understanding of the impact of varying tillage practices and P fertilizer placement on P loss would lead to better P management on sugar beet production fields.

Materials and Methods

The experimental site was located in Chippewa County, Minnesota near Raymond, Minnesota on a Colvin-Spicer silty clay loam (fine-silty, mixed, superactive, frigid Typic Calciaquoll and fine-silty, mixed, superactive, calcareous, mesic Typic Endoaquoll) complex. The study was conducted during the 2000 and 2001 growing seasons. Runoff samples were collected in the summer of 2001.

The experimental was set up as a split-plot design replicated three times. The whole plot treatments (44 X 50 ft) were tillage/crop rotation system. The treatments were as follows: (1) corn/soybean rotation, with moldboard plow as primary tillage before soybean; (2) corn/soybean rotation, with chisel plow as primary tillage before corn; (3) sugar beet/soybean/corn rotation, with moldboard plow as primary tillage before sugar beet and chisel plow as primary tillage before soybean and corn; (4) sugar beet/soybean/corn rotation, with a DMI chisel plow as primary tillage before sugar beet and chisel plow as primary tillage before soybean and corn; and (5) sugar beet/soybean/corn rotation, with a DMI chisel plow as primary tillage before sugar beet, chisel plow as primary tillage before soybean and corn, and a spring cover crop of oats planted before sugar beet.

Whole plots were then split into a 8- 22 inch row subplot 17.7 X 50 ft in size. The two split plot treatments were phosphorus application methods of (1) broadcast application of 40 pounds phosphate per acre and (2) knife injection of 40 pounds phosphate per acre placed at a depth of 5 inches. Phosphorus fertilizer use was triple super phosphate (0-44-0). Phosphate fertilizer applications were completed in the spring prior to secondary tillage.

A rainfall simulator was used to generate runoff. Rain simulations took place on soybean in whole plot treatment 1, corn in whole plot treatment 2, and sugar beet on whole plot treatments 3, 4, and 5. An average rainfall intensity of 2.2 inches per hour was applied to each rain simulation plot.

Runoff was collected to determine runoff flow rate and P concentration. Runoff samples were taken over a period of one hour. Samples for orthophosphate and TP analysis were placed on ice and in the dark until they were transported to the lab for analysis. Orthophosphate was analyzed colormetrically on decanted samples using the method outlined by Murphy and Riley (1962). Total P was analyzed by the same method, after aggressive mixing of the sample and its digestion with sulfuric acid and mercuric acid (Olsen and Sommers, 1982). Particulate P was calculated as the difference between TP and DP.

Soil test P was analyzed using the Olsen-P soil test (Frank et al., 1997). The line intersect method (Laflen et al., 1981) was used to determine residue cover. Soil moisture samples were taken immediately before rainfall simulation, dried at 140 degrees F, and reported as %. A survey grade Astech GPS unit was used to determine slope of the landscape.

Results and Discussion

A summary of the means and ranges of DP, PP, and TP concentrations and contents can be found in Table 1. Also included in Table 1 are the means and ranges of soil and landscape characteristics. Analysis of variance (AOV) results show no significant differences in DP, PP, or TP content among tillage/crop rotation and between P fertilizer applications (Table 2). The results were similar for DP, PP, and TP concentrations. No practical differences were found. This may be a result of the nearly level landscape (0.6 to 2.8 %) landscape. The level landscape influenced the small runoff flow rates and sediment loss. Also, the residue cover values are inconsistent with what might be expected for different primary tillage systems. By the time of residue measurement (June 2001), the soil had been tilled with a field cultivator and planting had occurred. The effects of primary tillage on P loss were lost.

Table 1. Means and ranges of P loss, runoff, sediment, soil characteristics, and land characteristics.

			Range	
Property	Unit	Mean	Minimum	Maximum
DP content	lb P/A	0.16	0.07	0.33
PP content	lb P/A	0.73	0.21	1.75
TP content	lb P/A	0.90	0.29	1.96
DP concentration	ppm-P	0.96	0.46	1.80
PP concentration	ppm-P	4.32	1.10	10.72
TP concentration	ppm-P	5.28	1.89	12.52
Runoff	ml/second	6.38	2.53	18.83
Sediment loss	Lb/A	616	98	3429
Residue cover	%	8.5	3.0	12.3
Olsen-P soil test	ppm	40	9	109
Soil moisture	%	35.5	30.5	40.3
Slope	%	1.87	0.63	2.82

Table 2. Effect of primary tillage and P fertilizer application method on P concentration and P content in the runoff.

		P concentration in runoff			P content in runoff		
		Dissolved P	Particulate P	Total P	Dissolved P	Particulate P	Total P
Crop grown	Primary tillage	-------------- ppm -------------			-------- pounds P per acre --------		
Soybean	Moldboard plow	0.77	3.75	4.52	0.21	1.06	1.28
Corn	Chisel plow	1.06	4.95	6.01	0.22	1.14	1.37
Sugar beet	Moldboard plow	0.68	2.96	3.64	0.22	0.96	1.18
Sugar beet	DMI chisel	0.92	3.81	4.73	0.16	0.59	0.75
Sugar beet	DMI chisel plus cover crop	1.36	6.04	7.41	0.21	0.92	1.12

P fertilizer application method						
Broadcast	0.94	4.21	5.15	0.19	0.84	1.02
Knife injected	1.00	4.46	5.46	0.22	1.04	1.27
Statistical analysis	NS	NS	NS	NS	NS	NS

To understand what factors did effect P losses on this landscape regression analysis was used. The regression models developed included either a source variable such as soil test P or a transport variable such as amount of runoff water or sediment loss. For dissolved phosphorus only the soil phosphorus was important. The greater the soil test P the greater the concentration of dissolved phosphorus in the runoff. Soil test P and the amount of sediment moved by erosion was important for understanding the concentration and content of particulate P and total P that is lost from the landscape. Overall, the transport factors are the most important for predicting P loss from this landscape. If a grower can control erosion, they can limit P loss into fresh water bodies in the Southern Minnesota Beet Sugar Cooperative growing areas.

Conclusions

This study concluded no differences in P loss from any management practices related to sugar beet production. It also found no differences in P loss between sugar beet production systems and a corn/soybean rotation system. Phosphorus losses were also not influenced by any primary tillage (including a spring cover crop of oats) system or by the P fertilizer application method. Runoff flow rate or sediment loss was not affected by any management systems. This is most likely a result of the typically level lands that are used in sugar beet production.

The regression analysis indicate that reducing the soil test P levels, runoff, and sediment losses would provide an effective way to reduce P losses

.

References

Frank, K., D. Beegle, and J. Denning. 1997. Phosphorus. In Recommended Chemical Soil Test Procedures for the North Central Region. (Ed.) J.R. Brown. North Central Regional Research Publication No. 221 (revised) pp. 21-29.

Kimmel, R.J., G.M. Pierzynski, K.A. Janssen, and P.L. Barnes. 2001. Effects of tillage and phosphorus placement on phosphorus runoff losses in a grain sorghum-soybean rotation. J. Environ. Qual. 30:1324-1330.

Laflen, J.M., and M.A. Tabatabai. 1984. Nitrogen and phosphorus loss from corn-soybean rotations as affected by tillage practices. Trans. Am. Soc. Agric. Eng. 22:58-63.

Laflen, J.M., M. Amemiya, and E.A. Hintz. 1981. Measuring crop residue cover soil erosion on cropland. J. Soil and Water Cons. 36:341-343.

Murphy, J., and J.P. Riley. 1962. A modified single solution method for the determination of phosphate in natural waters. Anal. Chem. Acta. 27:31-36.

Olsen, S.R., and L.E. Sommers. 1982. Phosphorus. In Method of Soil Analysis. Part 2. 2nd edition. (Ed.) A.L. Page et al. Agron. Monograph 9. ASA and SSSA, Madison, WI.

Sharpley, A.N., 1995. Identifying sites vulnerable to phosphorous loss in agricultural runoff. J. Environ. Qual. 24:947-951.

Sharpley, A.N., S.C. Chapra, R. Wedepohl, J.T. Sims, T.C. Daniel, and K.R. Reddy. 1994. Managing agricultural phosphorus for protection of surface water: issues and options. J.Environ. Qual. 23:437-451.

Sharpley, A.N., S.J. Smith, O.R. Jones, W.A. Berg, and G.A. Coleman. 1992. The transport of bioavailable phosphorus in agricultural runoff. J. Environ. Qual. 21:30-35.

U.S. Environmental Protection Agency. 1996. Environmental indicators of water quality in the United States. EPA 841-R-96-002.