CANADA

Cropping Effects on Phosphorus Leaching in Clay Soils

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Subsurface runoff is now recognized as an important source of P contamination in surface waters of areas characterized by intensive animal production. This is particularly the case in the flat clay soils in cool and humid climates. These soils have a much smaller P storage capacity than comparable soils from warmer climates. The use of best management practices (BMPs) and conservation tillage, while effective in limiting surface erosion, does not always significantly reduce the amounts of P lost by drainage. The choice of crops may play an important role in the load of P from subsurface runoff.

While losses of sediment by erosion have traditionally been considered the greatest source of the problem in eutrophication of aquatic systems, phosphorus (P) in subsurface water flow is now recognized as another important source. Recent findings indicate that total P losses to aquatic systems can actually be higher under legumes and forage crops than under corn or barley.

Subsurface water from tile drainage effluent under three cropping systems was analyzed over the 1961-1967 and 1980-1981 periods. This study was initiated in 1959 on a Brookston clay soil in southwestern Ontario. It included two fertilizer treatments (0 and 70 lb/A of P_2O_5) applied each year since 1960. The three cropping systems were continuous corn, a corn-oats-alfalfa-alfalfa rotation, and permanent Kentucky bluegrass. The results of the first period indicate limited effect of cropping systems, whereas P addition slightly increased P losses (**Table 1**). In European countries and in the U.S., a P concentration greater than 0.15 parts per million (ppm) is considered critical for the proliferation of algae.

The results of the fertilized plots from the second period indicate much larger losses to drainage water from the rotation plots than from continuous corn. The losses were particularly high under bluegrass. Even though no P fertilizer was added in the two alfalfa years, tile drainage P loss was still larger than under corn. In the unfertilized plots, P losses decreased between the first and second periods. However, crop yields were also reduced by 42 to 64 percent under these low soil fertility conditions.

What explains these observations? First of all, permanent forages (such as Kentucky bluegrass) are never plowed. Therefore, the network of biopores is never broken by the plow, and this may help the preferential flow of applied P to the drainage tiles. Further, the rotation crop is plowed under twice in the 4-year cycle (i.e. after corn and second year alfalfa). Secondly, grasses have greater root activity, and their roots exude more carbon (C) into the soil. Thirdly, organic acids from buried legume residues

TABLE 1. Average P content (ppm) of drainage water from soils cultivated to different crops in Harrow, Ontario.

Time period	Fertilizer	Monoculture corn	Rotation corn	Oats	1st year alfalfa	2nd year alfalfa	Kentucky bluegrass
1961-67	zero	0.17	0.20	0.17	0.20	0.18	0.17
	NPK	0.19	0.22	0.19	0.21	0.27	0.19
1980-81	zero	0.04	0.06	0.05	0.05	0.04	0.05
	NPK	0.14	0.39	0.47	0.48	0.39	1.10

diminish the P storage capacity. Phosphorus may migrate in organic forms along with dissolved organic C to reach the drainage system.

In addition to P in tile drainage water, surface runoff water was also monitored for dissolved and sediment P. In this experiment continuous corn had the highest sediment P in the surface runoff (data not shown). However, total dissolved P was much greater under sod than under continuous corn (**Table 2**). Rotation corn, oats and alfalfa had intermediate levels of surface water P losses.

TABLE 2. Total losses of phosphorus in surface runoff during growth of different crops in Harrow, Ontario.

Crop	Total P losses, lb/A
Continuous corn	0.69
Bluegrass sod	3.12
Rotation corn	1.09
Oats	1.25
First year alfalfa	1.10
Second year alfalfa	1.28

In a second study, we are investigating the effect of crops in a long-term experiment at our research farm at Normandin, Quebec. We have measured the amount of water soluble inorganic P in the subsoil of a clay at five times during the growing season: 15 days before and after seeding, 45 days after seeding, at harvest and 15 days after fall tillage operations. The results presented in **Figure 1** are averaged over six years (1989 to 1995). They clearly show that water soluble P content in the subsoil is much larger, particularly in the spring, under forages than under spring barley. This soil is rated as low in P by the Mehlich 3 soil test. Significant relationships were established between the amounts of water soluble C and P.

In the subsoil, a soluble P concentration greater than 1 part per million (ppm) is considered high. Although the mechanism is under investigation, results from these two studies indicate that subsoil runoff is potentially larger under forages than under cash crops in these cool and humid clay soils. This should be taken into consideration when implementing BMPs to reduce P losses to drainage waters in similar soils.

These findings radically alter the perception of the environmental impacts of cropping systems previously

(continued on page 27)

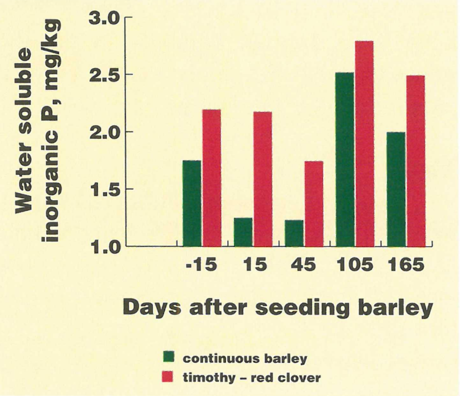

Figure 1. Water soluble P in the subsoil (2 to 3 ft. depth) of a Normandin clay soil in Quebec, averaged over the period 1989 to 1995.

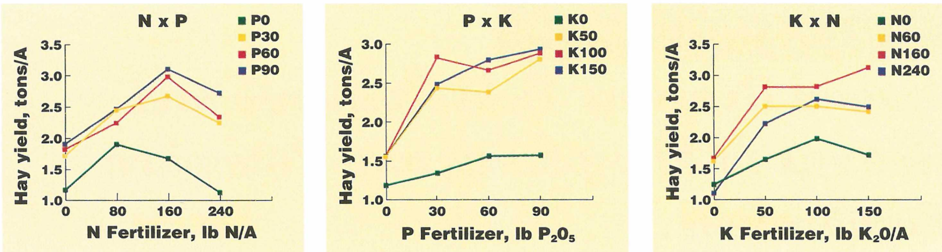

Figure 1. Effect of applied N, P, and K on total forage yield (average of 1985 and 1986). Forage yields expressed as hay at 18 percent moisture content.

species when low levels of K were applied. The proportion of bluegrass increased with increasing levels of applied P.

Soil

Applications of large amounts of N decreased soil pH of the topsoil by more than 1.3 units. This decrease was also observed at a depth of 18 inches. The decrease in pH, however, was less when P fertilizer was also applied because of the presence of calcium (Ca) in the superphosphate. Some fertilizer P was translocated into the 12- to 18-inch depth. The amount of P translocated increased with increasing rates of applied P.

Soil organic carbon (C) in the 0- to 6-inch layer ranged from 2.2 to 3.7 percent after 26 years and from 2.6 to 4.4 percent after 35 years. Organic C was greatest in plots with the lowest biomass production. Conversely, soil in plots with the greatest biomass production had the least amount of soil organic C. The differences were likely related to greater amounts of dry matter partitioned to non-harvested plant parts of the less productive forage species.

Conclusion

Long-term production of timothy is possible with balanced applications of N, P and K. The changes over time in response to P fertilizer, botanical composition, soil pH, and the movement of P would not have been predicted from short-term studies of three years or less. Fertility requirements of perennial forage crops are not well defined by field trials of short duration. BC

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Cropping Effects...

(continued from page 25)

considered desirable. While grass and forage crops protect soil from erosion and reduce impacts of sediment loss, corn and grain cultivation may have a more positive environmental impact when total P losses to aquatic systems are considered. BC

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