HIGH SOIL PHOSPHORUS – IS IT A PROBLEM IN MANITOBA?1

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ABSTRACT

The majority of Manitoba’s soils do not have sufficient phosphorus (P) for optimum crop production, however localized areas have surplus P, largely due to excessive manure from concentrated livestock operations. The fertilizer industry supports the concept of nutrient management planning where surplus P threatens water quality and the environment, but recognizes the need for flexible and site-specific management.

MANITOBA’S FERTILIZER CONSUMPTION

On a per acre basis, Manitoba farmers use more fertilizer than in any of the other Prairie Provinces. In the last five years provincial farm expenditures on fertilizer and lime have averaged about $318 million annually (Korol and Rattray 2001). Nitrogen (N), P and potassium (K) are essential to produce good yielding crops. Consumption of these nutrients has closely paralleled increasing trends in crop production during the past few decades (Fig. 1). It is estimated that fertilizers currently contribute at least a third, or more of total crop yield.

Figure 1. Production of major crops and total N, P2O5 and K2O sold in Manitoba between 1965 and 2000. (Source: Statistics Canada Crop production series and Korol and Rattray, 2001).

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Phosphorus is the second most limiting nutrient to crop production, behind N. Annual P consumption, like total fertilizer use, has steadily increased from about 18,000 tonnes in the mid 1960’s to almost 116,000 tonnes today (Fig. 2). Phosphate presently accounts for 19 percent of the total fertilizer sold in Manitoba.

![Figure 2. Consumption of fertilizer N, P2O5 and K2O in Manitoba from 1965-2000 (Source Korol and Rattray 2001)](image)

**P STATUS OF MANITOBA SOILS**

The Potash & Phosphate Institute surveyed commercial laboratories for soil samples collected in Manitoba from the fall of 2000 and spring of 2001 (PPI 2001). They reported that 73 percent of the approximately 15,000 fields sampled tested medium or less in plant available P. An earlier survey conducted in 1996-7 reported that 80 percent of Manitoba soils were testing medium or lower (PPI 1998). Soils testing medium or lower will usually respond to P fertilization resulting in crop yield increases.

It shouldn’t be surprising that available soil P has remained relatively constant over time, even with increasing P use, because crop removal of P has exceeded that applied in fertilizer. Figure 3 shows a simple P balance from 1965 through 2000. It was updated from an earlier budget calculated from estimates of the P₂O₅ removed in grain and hay in major crops based on typical nutrient concentrations (Doyle and Cowell 1993). Phosphate removed in harvested crops has been fairly well matched to P added in fertilizer up to the early 1990’s. In recent years P application with fertilizer has exceeded crop removal. A regional budget that considers only fertilizer and crop removal provides a broad overview of P inputs and outputs in Manitoba, and while it suggests that the Province as a whole is doing a good job managing P, it is too general to identify specific areas of concern or pin point potential problems.
Determining a more detailed P budget can be challenging because local data is often difficult to obtain. Nevertheless, a more thorough budget that included P removal by crops, and P additions from both fertilizer and manure were developed using the 12 Agricultural Regions of Manitoba for this paper. Specifics on the process of determining these values for the production year 2000 are as follows:

- Crop and livestock data was obtained from the 2000 issue of the Manitoba Agriculture Yearbook (Manitoba Agriculture 2001).
- Production data for the crops grain corn, all wheat, barley, oats, rye, canola, flax, potatoes, alfalfa and tame hay were used as they represent in excess of 95 percent of total crop production in the province. The distribution of alfalfa, grain corn and potato were determined using the 1996 Census of Agriculture (Statistics Canada 1997) and consultation with Manitoba Agriculture (Bill Moon, personal communication).
- The values for nutrient removal per unit of yield were obtained from the Potash and Phosphate Institute website (http://www.ppi-ppic.org/ppiweb/canadaw.nsf).
- Fertilizer P consumption for 2000 was obtained from the Agriculture and Agri-Food Canada statistics branch (Korol and Rattray 2001). Given that only provincial totals for fertilizer nutrients are available, we assumed that the use of P was proportional to the purchase of total fertilizer and lime in each Agricultural Region, as detailed in the 1996 Census of Agriculture (Statistics Canada, 1997).
- Manure nutrients were determined using livestock numbers from the Manitoba Agriculture Yearbook, and recoverable manure nutrient calculated using the method described by the USDA-NRCS (Kellogg et al. 2000).
- It is important to clarify that these are estimates, and by no means should be considered a definitive balance, given the nature of the available data and the assumptions made.
**Fertilizer P\(_2\)O\(_5\)** met or exceeded crop removal in 8 of the 12 regions, with the remaining 4 showing a negative balance (Table 1). The amount of recoverable manure P\(_2\)O\(_5\) ranged from 1.0 to 11.5 lb/A. When manure is included in a P\(_2\)O\(_5\) budget, Manitoba’s 12 agricultural regions had an average P\(_2\)O\(_5\) surplus of only 5.6 lb/A. However, the budget ranged from a deficit of –3.4 lb/A to an excess of 23.3 lb/A. The surplus/deficit was almost balanced (± 5 lb P\(_2\)O\(_5\)/A) in seven regions and exceeded 5 lb P\(_2\)O\(_5\)/A in five regions. These regions with a high surplus have large livestock populations and/or potato production.

Table 1. Estimated P\(_2\)O\(_5\) in crop removal, fertilizer application and recoverable manure nutrients on a per acre basis for the 12 Agricultural Regions of Manitoba in 2000.

<table>
<thead>
<tr>
<th>Agricultural Region</th>
<th>Crop Removal</th>
<th>Fertilizer Applied</th>
<th>Recoverable Manure</th>
<th>Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18.1</td>
<td>15.7</td>
<td>1.2</td>
<td>-1.2</td>
</tr>
<tr>
<td>2</td>
<td>18.4</td>
<td>20.3</td>
<td>2.0</td>
<td>3.9</td>
</tr>
<tr>
<td>3</td>
<td>17.3</td>
<td>20.1</td>
<td>1.4</td>
<td>4.1</td>
</tr>
<tr>
<td>4</td>
<td>14.5</td>
<td>14.9</td>
<td>1.1</td>
<td>1.5</td>
</tr>
<tr>
<td>5</td>
<td>24.7</td>
<td>20.3</td>
<td>1.0</td>
<td>-3.4</td>
</tr>
<tr>
<td>6</td>
<td>17.6</td>
<td>17.0</td>
<td>1.3</td>
<td>0.8</td>
</tr>
<tr>
<td>7</td>
<td>18.5</td>
<td>27.7</td>
<td>3.2</td>
<td>12.3</td>
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<tr>
<td>8</td>
<td>21.6</td>
<td>26.2</td>
<td>3.2</td>
<td>7.8</td>
</tr>
<tr>
<td>9</td>
<td>15.1</td>
<td>26.9</td>
<td>11.5</td>
<td>23.3</td>
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<tr>
<td>10</td>
<td>13.1</td>
<td>14.5</td>
<td>6.2</td>
<td>7.7</td>
</tr>
<tr>
<td>11</td>
<td>16.8</td>
<td>23.1</td>
<td>4.4</td>
<td>10.7</td>
</tr>
<tr>
<td>12</td>
<td>17.0</td>
<td>13.0</td>
<td>4.0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>17.7</strong></td>
<td><strong>20.0</strong></td>
<td><strong>3.4</strong></td>
<td><strong>5.6</strong></td>
</tr>
</tbody>
</table>

Management of manure from confined livestock operations still requires a large land base, with the size dependent on an agronomically realistic rate of manure application. A USDA-NRCS study found that in 1997, those confined livestock facilities with more than 1000 animal units (AU) in the United States averaged 1.7 AU per acre (Kellogg et al., 2000). In fact, because many of these livestock facilities have very high numbers of confined AU’s, they found that on a farm-level basis, 60% of the recoverable N and 65% of the recoverable P were considered in excess of the land base of the farms they were generated on. Taking the recoverable manure nutrients to all of the lands in the county that the livestock operations exist, still does not allow for the application of manure in a manner that would avoid loading in excess of crop removal. As a result, given the high cost of transporting raw manure to any great distance, over-application of nutrients can quickly become a serious problem.

The challenge when using manure nutrients in any nutrient balance in agriculture is that of distribution of these nutrients. Current technology for the processing of manure is limited, and relative to commercial fertilizer sources, prevents any economically realistic redistribution of the nutrients in manure away from confined livestock operations. So when we consider manure nutrients in the balance of inputs and outputs, it is important to realize that they are not uniformly distributed in the region being considered. In fact, with the growth of large confined animal feeding operations they are concentrated at very high levels on a small land base adjacent to the facility.

**ENVIRONMENTAL ISSUES AND SOLUTIONS**

The majority of Manitoba’s soils do not have sufficient plant available P to produce the yields that farmers need. Despite this, there is growing concern that farmers apply too much P resulting in nutrient overloading that has a negative impact on water quality. However, Manitoba is not alone in addressing concerns regarding P in the environment. More than 90 percent of 700 streams, lakes and
Phosphorus is an extremely immobile nutrient in the soil. It is strongly adsorbed on the surface of soil particles and forms stable, insoluble compounds with ordinary soil constituents like calcium, aluminum, and iron. These reactions explain why P is commonly a limiting nutrient for plant growth and why P inputs are needed for crop production. Because P is immobile and insoluble in the soil, it often limits the growth of aquatic plants and algae in surface waters. However, if excessive P is lost in runoff, enrichment or eutrophication of lakes and other non-flowing bodies of water can occur, causing undesirable algal blooms and heavy growth of aquatic plants.

Most of the P enrichment of aquatic systems has come from sewage disposal plants (Smil 1999), but manure disposal from concentrated animal feeding operations for cattle, swine and poultry is becoming an increasingly important environmental problem that requires special management. When applied correctly and at a proper application rate, P has such a strong affinity for soil particles that the amount coming from agricultural lands is insignificant. The loss of P to surface waters is an environmental risk that can be almost eliminated by controlling erosion and runoff factors that influence P transport and through appropriate P management.

Runoff carries suspended soil particles and the P associated with them. It also carries small concentrations of dissolved P, but dissolved P in runoff waters is of lesser concern. Tillage management can have a dramatic effect in reducing runoff P losses. For example, converting half a paired watershed in a wheat growing area in Oklahoma to no-till management reduced the concentration of total P in runoff by more than 80 percent (Figure 4).

Phosphorus is not likely to pose any environmental threats when application rates of manure and fertilizers are based on soil test recommendations, rates do not greatly exceed crop removal, and good agronomic management practices are employed. At a regional level there doesn’t appear to be a problem with surplus P in Manitoba, but there are localized areas with excess P.

The fertilizer industry supports the concept of nutrient management planning where surplus P threatens water quality and the environment, but recognizes the need for flexible and site-specific management. Nutrient management planning should be science-based, utilize on-farm nutrient sources and employ well-established management practices. These may include soil testing and tissue testing, manure analysis, proper nutrient application methods and timing, conservation tillage, vegetative buffers, riparian zones and other available technologies.

Soil testing is an important component of nutrient management planning and its agronomic use is well recognized, but its environmental use needs further refining. Interpretation and critical levels for crop response have been determined by greenhouse and field experiments. Interpreting soil tests for
environmental purposes should follow the same process used for agronomic interpretation, i.e. evaluation of extractants, analytical methodology and calibration to reflect environmental impact.

Calibration and interpretation of soil tests to predict environmental impact potential is more complicated than for crop response (CAST 2000). Determining nutrient loads that prevent water-quality degradation depends on the proximity to sensitive water bodies, the use of the water, socioeconomic factors of rural land use, and other site-specific factors. A critical soil test level for nutrient pollution is not likely to be found.

All nutrients do not behave similarly in the soil, nor pose similar environmental risk, and all areas of a landscape will not contribute equally to nutrient loss. Excess N is easily leached or lost in runoff accumulating in groundwater and watersheds and may contribute to low dissolved oxygen (hypoxia) in the shallow coastal waters, whereas K is environmentally benign. Phosphorus, whether applied as fertilizer or in animal wastes moves very slowly in the soil because of adsorption to soil particles or precipitation with other soil minerals. Controlling erosion will greatly reduce or eliminate the risk of P loss in runoff. However, when soil P levels become very high due to repeated manure applications or over-fertilization, runoff losses of P increase.

High levels of soil P may also lead to leaching of soluble P in certain situations. If the sorption capacity of the surface soil becomes saturated, dissolved P can move through the soil profile. In most soils P leaching is insignificant due to fixation by P-deficient subsoil, but in soils with a low fixation capacity (i.e. sands, acid organic or peat soils) and that have high volumes of water percolation, P can move.

Risk of P loss depends on the nutrient source and a mechanism for transport. Topography, soils and cropping systems are diverse making the development of a uniform environmental threshold P level unreasonable or inapplicable across all agricultural areas. The P index is an example of an approach that utilizes soil testing and incorporates erosion, leaching, runoff potential and proximity to sensitive water to assess areas of potential risk. In addition to soil testing, it includes fertilizer and manure rates and methods of application.

Applied research has shown that the P-index is a useful tool in predicting critical areas of fields susceptible to P loss (Synder et al. 1999). For example, a study on a 98-acre watershed in Pennsylvania planted to soybean, wheat, or corn (50 percent), pasture (20 percent) and woodland (30 percent) was intensively sampled (100-foot grid) and was found to have P levels ranging from 7 to 788 ppm. No P would be recommended on 52 percent of the samples because soil test P was above optimum (30 to 100 ppm P) and based strictly on a soil test interpretation (i.e. threshold level) application would be restricted on 63 percent of the cropland. However, application of a P-index in each of the grid areas revealed that only 15 percent of the watershed was at risk for P transport losses to the stream.

The P-index provides a practical means to rate the potential for offsite losses of P through runoff in areas with excess soil P levels, or other areas, which may be prone to P loss, and is an approach generally favored by the fertilizer industry. Critical soil test P levels, or threshold P levels are less favored because of concern they could preclude P application (i.e. starter P or manure disposal) on soils that pose no environmental threat, especially if the threshold is set too low.

Agronomically, the probability of crop response to P declines at high soil test levels, but even at high soil test levels crops can respond to supplemental P fertilization, especially starter applications. Figure 5 shows Saskatchewan data where annual applications of 16 lb P₂O₅/A have increased spring wheat yields while building soil test P levels. Responses are still occurring although soil test levels have increased to a high level. Profitable response to starter P on soils testing very high in P have been observed frequently on many soils in North America in a variety of crops when other production factors are optimum or when soils and climatic conditions impose stress early in the growing season (Griffith 1992).
How much soil test P is too much? There is no agronomic reason or need for soil test levels to be more than about 100 lb P/A. Relative crop yields plateau at high soil test P levels, but high amounts of P are not toxic and would not be a problem except P limits biological activity in lakes and streams and very small increases can accelerate eutrophication. The challenge with a threshold soil test P level is in setting it at a level that minimizes eutrophic runoff, without unduly restricting P application on soils and management systems that can safely accommodate higher levels of P.

In the U.S., regulatory threshold limits have been set in Colorado, Kansas, Maine, Maryland, Mississippi, Oklahoma, and Texas (Lory and Scharf 1999). Threshold soil test levels range from about 20 to 200 ppm, depending on the extractants and the sensitivity of the watershed. Regulatory limits are being considered in Vermont and Illinois and many other states recommend no further application of P above agronomic critical levels.

Soil tests are good indicators of when appreciable amounts of dissolved P may be in runoff. Research has clearly shown that dissolved P in runoff is positively correlated with soil test P (Pote et al. 1999).
1996). However, soil tests do not offer any indication of the amount, or rate of runoff water that may generated for a given set of conditions, nor the total P that may be leaving the field. The variables and unknowns in the movement of P in a given landscape make environmental impact difficult to assess based solely on a threshold soil test P level.

Phosphorus management, whether dealing with surplus P due to manure, or inherent P deficiency due to crop needs should be site-specific. The fertilizer industry recognizes that management of P and other nutrients is critical to the well being of our industry and the protection of our environment. It also recognizes the challenges of nutrient management evolving with concentrated livestock operations and the opportunities manure provides as an alternative nutrient source. Manure is a valuable nutrient source and needs to treated as such. Putting too much in one place in a waste of nutrient resources

There are indications that partnerships are emerging within the fertilizer and livestock industries to develop new technologies to economically beneficiate and recycle nutrients in manure where surpluses exist. The nutrient value of manure has always been recognized, but its low analysis has precluded its unprocessed use beyond areas within 10 to 12 miles of its origin. With recent advances in composting and the emergence of operations that are commercializing manure and producing higher analysis products, there will be greater opportunities to utilize manure as a valuable nutrient source.

In summary, surplus P from manure is a serious problem in a few small areas of Manitoba. Farmers, crop advisors, input and service suppliers, researchers, government agencies and industry will need to work together to solve potential problems related to nutrient management. It is important that localized, or site-specific approaches be employed to prevent unnecessary constraints on productivity. The majority of Manitoba’s agricultural soils are low in P and require fertilization. Where possible, and where economically feasible, the nutrients in manure should be utilized. However, care must taken to ensure manure nutrients are utilized in ways that will maximize crop production, and minimize impact on the environment.

REFERENCES


