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An Agri-Environmental Model for Potato Phosphorus Recommendations

By L. Khiari and L.E. Parent

Phosphorus fertilization is essential for obtaining high potato yields, but it is also a potential non-point source of water pollution. Potato farmers usually apply P in large excess of P removal by the crop since the potato has limited root development and explores only a small portion of the soil volume. In addition, the potato crop is grown in acid soils, where added P is fixed to a great extent as Al and iron (Fe) phosphates.

Since the plant absorbs soluble P, and soluble P can affect the quality of surface water, a suitable agri-environmental P recommendation model for the potato crop should integrate the environmental risk and the crop response to fertilization. Part of the environmental risk is often assessed using a P saturation index, while crop response probability to fertilization is related to soil test P. We have found that a M-III P saturation index could be used to simultaneously assess environmental risk and make recommendations for the potato crop.

> A phosphorus (P) saturation index derived from the commonly used Mehlich-III (M-III) soil test can be an effective tool for the development of P fertilizer recommendations that simultaneously optimize potato yields and minimize risk of water contamination. The ratio of P to aluminum (Al) forms the basis for an integrated agri-environmental model.

Defining a P Saturation Index

The environmental risk of loss of P from the soil has been assessed in the Netherlands from the degree of P saturation (DPS), computed as P/(Fe+Al) from molar concentrations of oxalate-extractable P, Fe, and Al. Recently, the ratio of P/Al in M-III extracts was found to correlate closely

Researchers are seeking tools for development of P fertilizer recommendations that optimize potato yields and minimize risk of water contamination.

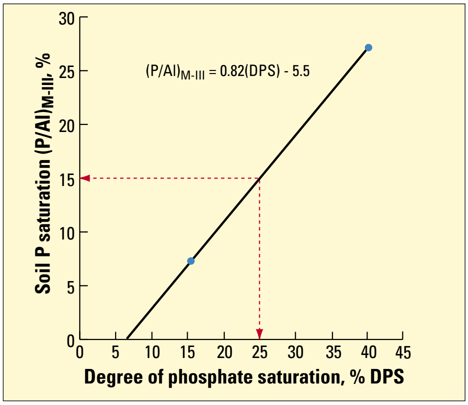

Figure 1. Relationship between degree of phosphate saturation (% DPS) and soil P saturation as $(P/Al)_{M-III}$.

with such P/(Fe+Al) molar ratios in Quebec soils. In our acid coarse-textured potato soils, we found by a fractionation procedure that soluble inorganic P was mainly sorbed by Al-oxyhydroxide (79 percent of added P), while Fe-phosphate made up only 9 percent of added P. Thus, P sorption in Quebec soils is related primarily to soil Al.

The DPS value of 25 percent used in the Netherlands as the environmental critical value corresponded to a $(P/Al)_{M\text{-}III}$ ratio of 15 percent [based on parts per million (ppm); see **Figure 1**]. Consequently, a P fertilizer rate exceeding P removal by the crop would be at risk environmentally for soils testing above 15 percent as $(P/Al)_{M\text{-}III}$. It must be ascertained whether fertilizing the crop according to P removal above this critical value would negatively affect tuber productivity.

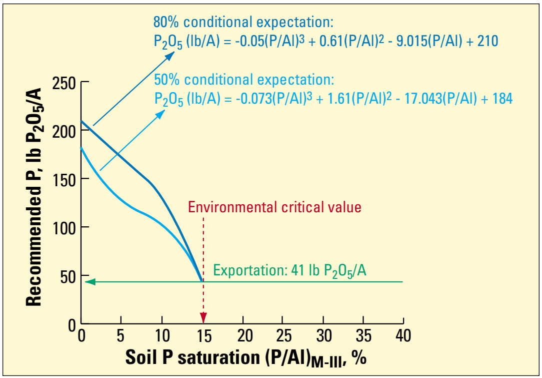

Figure 2. Agri-environmental P recommendation models for potato production in Quebec.

TABLE 1. Comparison of P recommendations for five example soils based on $P_{M\text{-}III}$ (CPVQ, 1996) or the $(P/Al)_{M\text{-}III}$ percentage (agri-environmental approach).

Mehlich-III determination			Recommended levels of P_2O_5, lb/A		
$P_{M\text{-}III}$, lb/A	$Al_{M\text{-}III}$, lb/A	$(P/Al)_{M\text{-}III}$, %	CPVQ (1996)	Conditional expectation 50%	80%
61	3,124	2.0	192	156	194
168	2,643	6.4	130	122	165
237	2,800	8.5	94	111	147
313	2,180	14.4	58	55	58
417	1,782	23.4	27	41	41

The Agronomic Model

In the agronomic model, we combined 78 field experiments conducted in Quebec over the past 30 years. Fertilizer trials were made of three blocks and three to six P levels in the range of 0 to 270 lb P_2O_5/A with 45 lb P_2O_5/A intervals. Percentages of total tuber yield were computed across experimental sites by dividing yield in the control plot by maximum yield in fertilized treatments, then multiplying by 100. Yield percentages were sorted in an ascending order of their $(P/Al)_{M\text{-}III}$ percentages. The partitioning between high and low response probabilities below and above a soil critical level was obtained iteratively using the Cate-Nelson procedure. The critical level as $(P/Al)_{M\text{-}III}$ was 8 percent, the starting value for constructing fertility groups.

In order to build an agri-environmental model based on the $(P/Al)_{M\text{-}III}$ percentage for making P fertilizer recommendations, agronomic and environmental models must be combined. As a result, five fertility and environmental risk groups were constructed as follows for potato production in Quebec acid coarse-textured soils:

- Extremely low fertility and extremely low environmental risk group: 0-2 percent as $(P/Al)_{M\text{-}III}$
- Very low fertility and very low environmental risk group: 2-4 percent as $(P/Al)_{M\text{-}III}$
- Low fertility and low environmental risk group: 4-8 percent as $(P/Al)_{M\text{-}III}$
- Medium fertility and medium environmental risk group: 8-15 percent as $(P/Al)_{M\text{-}III}$
- High fertility and high environmental risk group: greater than 15 percent as $(P/Al)_{M\text{-}III}$

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crop and P application on VAM colonization.

Corn seedling tissue P at the 3-leaf stage showed a positive response to fertilizer P addition. However, it was not influenced to any great extent by previous crop (**Table 1**). At the 6-leaf stage, previous crop did affect tissue P content significantly. As the season progressed, the influence of crop management or P addition had a minor impact on plant tissue P concentration (data not shown).

At harvest of the corn silage, the effect of previous crop was generally greater for the unfertilized than the fertilized treatments, with significant differences in 1998 (**Table 1**). While the differences were small, the trend over all trials was for increased corn yield and earlier maturity...as shown by lower percent dry matter (DM)...after corn than after fallow or canola. The trend was observed even when adequate P was applied.

The results of this research confirm what previous studies have shown. That is, the colonization of corn by VAM is influenced by previous crop in rotation. They also provide new information indicating that the colonization of corn roots by VAM was not negatively influenced by side banded P application, a treatment that in most instances improved the final silage yield and DM percent.

Early season colonization of corn roots by VAM had a positive effect on seedling tissue P concentration. Side banding P fertilizer can correct low P uptake associated with poor colonization of corn roots with VAM. However, this may not fully compensate for low P when there is poor root colonization. BC

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*An Agri-Environmental Model...**(continued from page 17)*

The P Recommendation Model

Optimum P rates were ranked in an ascending order within a given soil fertility group as defined above, and P rates corresponding to conditional expectations of 50th and 80th percentiles were recorded. The 50th percentile is the P rate at which 50 percent of the soils in the class produce an optimal yield. The 80th percentile is the P rate that produces optimal yield 80 percent of the time. Both P recommendation models are presented in **Figure 2**.

For recommendation models, the P rate stabilized at 41 lb P_2O_5/A for $(P/Al)_{M\text{-}III}$ exceeding 15 percent. For the 80 percent conditional expectation model, up to 200 lb P_2O_5/A would be recommended below 15 percent $(P/Al)_{M\text{-}III}$. Above an environmental threshold of 15 percent, the recommendation is 41 lb P_2O_5/A. Correspondingly, a P removal of 41 lb P_2O_5/A would be obtained with tuber yield of 375 cwt/A, assuming P removal of 0.11 lb P_2O_5/cwt of tubers. The largest difference between the present Quebec fertilizer recommendation, based on P alone, and the proposed model based on P saturation occurs above the 15 percent critical value (**Table 1**). Above 15 percent, our model recommends more P than present recommendations.

Thus, the $(P/Al)_{M\text{-}III}$ ratio provides a reliable and unifying criterion for making environmentally acceptable and agronomically efficient fertilizer P recommendations for sustaining potato production. The critical value of 15 percent for the $(P/Al)_{M\text{-}III}$ ratio appears to be an acceptable agri-environmental criterion for the potato crop grown in Quebec light-textured soils. A similar agri-environmental model is currently being developed for corn across a larger range of soil textural classes. BC

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