Nutrient Management

Conversion Equation Part I: Do Modified Morgan and Mehlich III P Have a Morgan P Equivalent?

Q. M. Ketterings, Dept. of Crop and Soil Sciences, Cornell Univ.; B. C. Bellows, Dept. of Agr. & Bio. Eng. Cornell Univ.; K.J. Czymmek, Pro-Dairy, Cornell Univ.; W.S. Reid, Dept. of Crop and Soil Sciences, Cornell Univ.; and R.F. Wildman, Agricultural Consulting Services, Inc.

Introduction

Cornell University publishes the "Cornell Guide" which includes recommendations for N, P, K, Ca, and Mg and micronutrients for a large number of field crops in New York. The recommendations are based on decades of field research showing that soil nutrients extracted by Morgan solution are correlated well with nutrient response for the vast array of soil types in NY.

Several private soil-testing laboratories that serve NY producers use the Mehlich-III and/or modified Morgan extraction solution. In the past, Cornell's fertilizer recommendation software did not allow for the use of extractants other than Morgan's solution because prior research conducted in NY demonstrated a poor relationship between Morgan and Mehlich-III extractable P (Klausner and Reid, 1996). However, comparisons within similar soil types (Pote et al., 1996), pH and textural class (McIntosh, 1969) or Al content (Magdoff et al., 1999) suggested it might be possible to derive better conversion equations (models) by including specific soil (chemical) characteristics in the equations. In 1999, Cornell University faculty and staff, agribusiness and state and federal agencies joined resources in a statewide study aimed at deriving such conversion equations for NY soils. In this article, we focus on P conversions. In a future issue of "What's Cropping Up?" we will address conversions for K, Ca, and Mg.

Field Sampling and Analyses

Personnel from Agway Inc., Agricultural Consulting Services Inc., ConsulAgr Inc., Cooks Consulting Services and the Miner Institute collected 235 soil samples (0-6 or 8 inches) in NY. These samples represented 27 soil types and eight major agricultural soil groups from across NY (Table 1).

The soil samples were analyzed at Cornell's Nutrient Analysis Laboratory, A&L Laboratories Inc., Brookside Laboratories Inc., and Spectrum Analytic Laboratories. A&L analyzed the samples for modified Morgan and Mehlich-III P. Brookside determined Mehlich-III P, K, Mg, Ca and Al while Spectrum generated pH and Mehlich-III P data. At Cornell, soils were analyzed for pH and Morgan extractable P, K, Ca, Mg, and Al.

In early 2000, Agricultural Consulting Services Inc. added the modified Morgan P extraction to its standard soil-sampling package. This generated a dataset of a 10,331 samples taken throughout NY with soil test P (STP) ranging from 1 to 559 ppm P (modified Morgan). This dataset, referred to as the ACS 2000/2001 dataset, was used to study the implications of using modified Morgan and/or Mehlich-III soil tests and a conversion equation on P fertilizer recommendations generated with Cornell nutrient management software.

Results[1]

The original 235 soil sample dataset covered an extensive range of soil chemical characteristics: 17-593 ppm Mehlich-III extractable P, 1-97 ppm Morgan STP, 380-1576 ppm Mehlich-III Al, 473-6025 ppm Mehlich-III Ca and 4.5-7.7 pH. Comparisons between Morgan and modified Morgan P analyses provided a close relationship: Morgan P (ppm) = 0.90*modified Morgan P (ppm). Mehlich-III P results from Brookside and A&L were virtually identical. Spectrum consistently measured a slightly higher (6%) P level.

Regression analyses between modified Morgan or Morgan and Mehlich-III extractable P (averages of Brookside and A&L) showed results similar to those reported by Klausner and Reid (1996); a very poor correlation (identified by a low r^2 value) existed when analyses were compared across all soil types and chemical characteristics. However, including pH, extractable Al, and Ca in the analysis resulted in greatly improved predictions:

Table 1: A total of 235 soils from 8 major agricultural areas in New York State were sampled to derive Morgan to Mehlich-III conversion equations. (#) = number of locations sampled per soil type. The soil type of four samples remained unidentified.

Northern Tier Till High lime	Southern Tier and Catskill Till – Acid	Valley and Lake Plain, lacustrine/marine	Outwash
A. Well drained	A. Well drained	A. Well drained	A. High pH
Honeoye (21) Ontario (21) Madrid (6) Hogansburg (6)	Lordstown (6) Mardin (21) Schroon (1) Bath (7)	Collamer (7) Hudson (3) Hamlin (3)	Arkport (6) Howard (3) Braceville (1)
B. Poorly drained	B. Poorly drained	B. Poorly drained	B. Low pH
Lima (2) Appleton (7) Ovid (11) Angola (3)	Volusia (30) Fremont (7) Malone (2)	Rhinebeck (18) Munuscong (1) Niagara (7) Madalin (1)	Chenango (29) Colonie (1)

$$\text{Morgan STP} = 1.617 + 0.5574*M3P - 0.001809*M3Ca - 12.97*pH + 0.05799*M3Al - 0.00002743*M3Al^2 + 1.2794*pH^2 + 0.00004445*M3P*M3Ca - 0.0009237*M3P*M3Al + 0.00000038*M3P*M3Al^2 \quad (r^2=0.88) \text{ [Model 1]}$$

In this equation *all data are in ppm*. Morgan STP is Morgan extractable soil test P, M3P is Mehlich-III extractable P, M3Al is Mehlich-III extractable Al, M3Ca is Mehlich-III extractable Ca, and pH is the soil pH in water (1:1). An r^2 value of 1 indicates a perfect correlation (and thus a very accurate prediction). For field data, an r^2 of 0.75 or higher is generally considered good.

Because most soil testing laboratories presently do not report Al in their standard packages, we developed a second equation without Al (all data in ppm):

$$\text{Morgan STP} = -55.53 + 1.366*M3P - 0.001284*M3Ca + 21.78*pH + 0.00005626*M3P*M3Ca - 0.5244*M3P*pH - 2.028*pH^2 + 0.0490*M3P*pH^2 \quad (r^2=0.82) \text{ [Model 2]}$$

Figure 1 shows measured versus predicted values for both models. Model [1] predicted 86% within 5 ppm (10 lbs/acre) of the measured value. The predictions for model [2] (i.e. no Al included) were slightly less accurate: 79% of the samples were predicted with a maximum deviation of 5 ppm (Figure 2). Deviations between measured and predicted values did not correlate with measured STP (i.e. deviations occurred throughout the range of measured soil test values).

Implications for Recommendations

Although a deviation of 10 lbs P/acre (5 ppm) in soil test P may seem large, such a deviation will not necessarily result in different P fertilizer recommendations. The "Cornell Guide" recommends a P application of 20 (±5) lbs P_2O_5/acre for corn grown on soils testing high for available P (9-39 lbs P/acre Morgan soil test P). No P addition is recommended for optimal economic yield when the STP is very high (≥ 40 lbs P/acre or 20 ppm P) while for soils with Morgan P levels less than 9 lbs P/acre, the recommendation is (65-[5*STP]) ±25%. In this calculation, STP is Morgan soil test P in lbs/acre. Recommendations are given as ranges because the relationship between soil test results and yield response is not perfect. The goal is to ensure that the true value for P

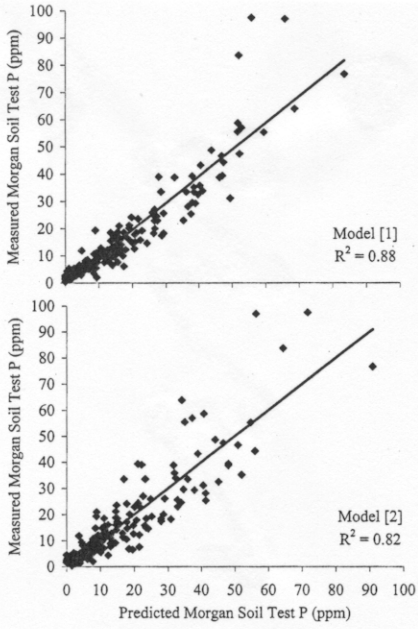

Figure 1: Measured versus predicted Morgan extractable P for 235 New York soils. Predicted values were obtained using a model that included Mehlich-III P, Ca, Al and pH as inputs (model [1]) and a model that included Mehlich-III P, Ca and pH only (model [2]). See text for the models.

application falls within the +/- 25% range 90-95% of the time.

We used the ACS 2000/2001 dataset to see how often we derive P recommendations for corn (using pH, Mehlich-III P and Ca and model [2]) that are not within the acceptable range. This comparison showed that for almost 60% of the 10,331 samples, recommendations based on predicted Morgan and those based on measured Morgan soil test P were identical. An additional 30% of the predictions generated 5-10 lbs P_2O_5/acre difference in recommendation and a total of 8% deviated 15-20 lbs P_2O_5. Almost 95% of the time, recommendations derived using pH, Mehlich-III P and Ca data fell within the $\pm$ 25% range. A slight improvement can be expected if Mehlich-III Al is included and model [1] is used for the conversion.

Conclusions

Cornell's fertilizer recommendations are based on the Morgan extraction solution. Thus, the most accurate recommendations are obtained using the Morgan solution for soil testing. However, the results of this study have shown that recommendations can be derived with modified Morgan as well as with Mehlich-III P input data if the soil pH and Mehlich-III Ca are known. The predictions can be improved by using an equation that includes Mehlich-III Al.

Conversions from other extractants (e.g. P Bray, Olsen) to Morgan P values may or may not correlate as well as the Mehlich-III to Morgan conversions in this study. Separate studies are needed to address conversions for other extractants. Separate studies are also needed if laboratory procedures are changed.

The P conversion models will be programmed into Cropware (Cornell's nutrient management software) that will be released in May 2001 and used to determine the NY P index for fields that have Mehlich-III soil test data. In a future article in "What's Cropping Up?" we will discuss Morgan equivalents for Mehlich-III K, Ca, and Mg.

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[1] All equations assume soil test values in ppm. To convert lbs/acre to ppm, divide by 2. To convert ppm to lbs/acre, multiply by 2.

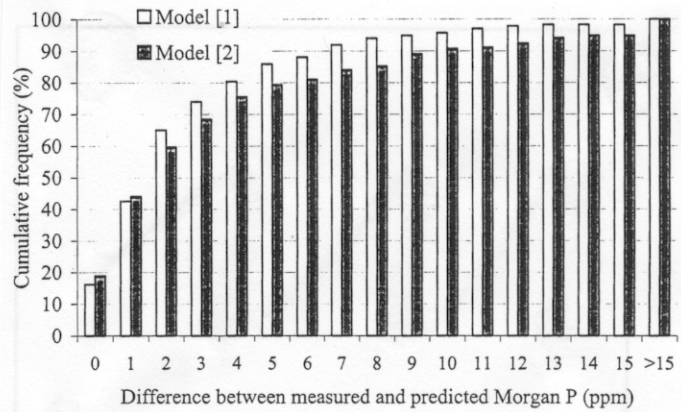

Figure 2: Cumulative percentage of samples as a function of the difference in predicted and measured Morgan soil test P for 235 samples from New York.