

Northern NY Agricultural Development Program 2011 Project Report

Project Title: Evaluating soil test phosphorus variation on NNY farms based on colorimetric and ICP determination methods: A preliminary investigation

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Cooperating Producers: Soil samples from various farms in Clinton, Franklin and Essex Counties were taken as part of this project. The names of the cooperating producers will be kept confidential for this project.

Background: Phosphorus (P) is a critical nutrient that can limit crop productivity and its management is an important environmental consideration on dairy farms. Agronomic and environmental P guidelines in NY are based on P extracted by the Morgan solution (sodium acetate). Fertilizer recommendations for P in NY are based on measuring P in the Morgan extract using molybdate colorimetry (e.g., spectrophotometer), which estimates the inorganic orthophosphate concentration in solution (biologically available P). Most soil laboratories also use inductively coupled plasma spectroscopy (ICP) to determine P and other nutrient cations in soil extracts. ICP measures multiple elements simultaneously and represents the *total* amount of an element in solution due to the high temperature plasma environment. Thus, soil test P (STP) measured by ICP may include organic and inorganic P. Several studies have reported that STP determined by ICP is often greater than STP measured by colorimetry (Pierzynski et al., 2005). The additional P measured by ICP reflects organic and/or particulate P forms not measured by the colorimetric procedure (Pierzynski et al., 2005).

The practical implication of the additional P measured by ICP is that it represents a potentially important plant-available P source once mineralized by soil microbes. Current agronomic P recommendations in NY, and nearly all land grant universities, do not account for this P or any organic P. A better understanding of P dynamics is needed to develop testing procedures for improved prediction of P availability, and will ultimately help dairy farms maximize P use efficiency and reduce P losses. The objectives of this project were to determine the extent of STP variation between the ICP and the colorimetric method for a large number of NNY soils, and to identify soil test factors influencing STP differences between the two methods.

Methods: In the fall of 2011, 244 soil samples were collected from different agricultural fields in Clinton, Essex and Franklin counties. The objective was to sample a range of soil properties representative of NNY. Samples were collected during October and

November 2011 by Champlain Valley Agronomics, Peru, NY. Standard agronomic soil sampling methods were followed. Approximately 15 cores were taken from each field to a depth of 8 inches. Samples were mixed thoroughly immediately following core collection in the field and a composite sample was taken for analysis. All samples were sent to the University of Maine Soil Testing Laboratory for analysis.

All major and micronutrients were extracted in pH 4.8 sodium acetate (original Morgan) at a 1:5 (v:v) extraction ratio for 15 min. Phosphorus was determined colorimetrically and by ICP. All other nutrient cations were measured by ICP alone. Soil pH was measured in distilled water. Organic matter was determined by loss on ignition at 500 C (2 hr) after oven drying at 110 C to constant weight. All solution analyses were run on the original (undiluted) soil extracts. Scooped volumes were weighed and all results are presented on an oven-dried weight basis.

Differences between STP measured by ICP and colorimetry were compared using linear regression procedures in SAS (SAS, 1999). In addition, the numeric difference between STP measured by ICP and colorimetry was modeled using stepwise multiple linear regression. The dependent variable was the difference in STP between the two methods and pH, organic matter, and extractable nutrient cations (with the exception of P) were used as the set of independent variables. The probability to enter the model was set $P=0.05$ and a value of $P=0.01$ was used to as the threshold to remain in the model.

Results and Discussion: Samples spanned a wide range in pH, organic matter, extractable nutrients and soil test P (Table 1, Appendix). The samples collected also represent a wide range in soil types, drainage capacity, and texture.

Although STP measured by ICP and colorimetry were highly correlated across all samples (Fig. 1), STP measured by ICP (STP-ICP) was consistently greater than STP measured by colorimetry (STP-Color). STP-ICP concentrations were 2.5 lb/ac greater than STP-Color averaged across all samples (Table 1). The ratio of STP-ICP to STP-Color increased strongly at STP-Color values <20 lb/ac (Fig. 2), indicating that unreactive P in the Morgan extract (presumed to be mostly organic) was greater at lower STP concentrations. At low STP levels, STP-ICP was as much 3.5-fold greater than STP-Color (Fig. 2). The greater difference between STP-ICP and STP-Color is also observed when a lower range of STP values is used for to compare the relationship between methods. For example, when STP-ICP values of ≤ 10 lb/ac are regressed with corresponding STP-Color values, STP-ICP was approximately 29% greater than STP-Color as predicted by the slope of the regression line (Fig. 3a). For STP-ICP values of <15 lb/ac, predicted STP-ICP values were approximately 18% greater than STP-Color (Fig. 3b). These relationships highlight the fact that unreactive P concentrations were greater at lower STP levels. Whether or not this additional P is plant-available is an open question that needs to be addressed. For manure, NY guidelines assume that all P (e.g., organic + inorganic) contributes to crop uptake, even though some fraction of this is likely fixed by the soil before plants can utilize it. For soils, it is likely that some portion of the soluble organic P is mineralized during the season and would contribute to the plant-available P pool.

Multiple linear regression analysis showed that soil organic matter (SOM) and aluminum were important explanatory variables influencing the difference between the two methods. Aluminum and SOM were both positively correlated with the numeric increase in STP-ICP over STP-Color and together explained 53% of the variation. It is well known that organic acids and Al readily form complexes with P, which may partially explain the direct relationship between greater unreactive P in solution and greater Al. Manganese and pH were also selected as significant ($P < 0.001$) predictors and explained another 4% of the variation (Table 2).

The use of ICP is standard instrumentation in most soil testing laboratories due to its ability to accurately measure multiple elements simultaneously. ICP measures the total amount of an element in an extract because the high temperature plasma environment releases organically bound elements. For elements that readily form bonds with carbon in soils such as P and sulfur (S), ICP measurements reflect the total quantity of the element (e.g., sum of organic and inorganic forms). In a recent NY study, Ketterings et al. (2011) suggested that measurement of sulfur in calcium chloride extracts with ICP showed the most promise as a soil test for S and was the most consistent detection method across soil types. Measurement of S by ICP also showed the greatest increase in soil test S per pound of S applied, which may be related to the fact that ICP measures both organic and inorganic S in solution.

Fertilizer P guidelines are based on STP-Color values in NY and most other land grant universities. Iowa State University is one of the only universities in the US that have developed STP calibrations based on both ICP and colorimetric determination methods (Mallarino, 2003). For example, the critical STP (based on Mehlich-3 extraction) level (e.g., where additional P is not expected to increase yield) for corn in Iowa based on the colorimetric test is ~20 mg/kg, whereas with ICP it is ~35 mg/kg.

Results from our study indicate that STP calibrations based on ICP for NNY soils would differ substantially from STP levels based on the colorimetric test. As a practical way to assess the relative agreement between the methods, NY STP categories were assigned to each sample and the percent agreement in categorizing STP status was calculated (Table 3). Not surprisingly, the poorest agreement occurred for the lower STP categories. For the “Low” STP category (using ICP-Color as the basis), there was only a 16% agreement between methods (Table 3). This means that ICP measurement classified 84% of the samples into the “Medium” STP category compared to the colorimetric test (e.g., classified as all “Low”). For STP levels classified as “Medium” by the colorimetric test, ICP measurement resulted in 43% of samples classified into the “High” STP category. Agreement dramatically improved to 99 and 100% for the “High” and “Very High” categories, respectively. Thus, the interpretation of STP depends on which method is used. For example, there is a difference of 20 lb P_2O_5 /acre recommended between the “Low” and “Medium” categories and the “Medium” and “High” categories, which is a difference of ~\$5/acre in potential fertilizer P costs (assuming ~\$0.60/lb P).

Conclusions/Outcomes/Impacts: Results from our study indicate that NNY agricultural soils may contain substantial organic P which may contribute to plant-available P. While our study did not directly measure organic P, results suggest that unreactive P in the Morgan extract was substantial in lower P testing soils. Results highlight the need to develop calibrations for NNY soils based on ICP and also indicate a need to further investigate the role of organic P in providing plant-available P. In addition, current NY P guidelines would benefit from further refinement based on accounting for differences in soil type, organic matter, and pH, all of which are known to affect P availability. Further research to develop and calibrate soil tests aimed at improving P availability, including organic P dynamics, is warranted. A better accounting of plant-available P has important economic and environmental implications for NNY farms.

Outreach: Project results will be presented at the 2012 American Society of Agronomy/Soil Science Society of America/Crop Science Society of America Conference. Other outlets for this work may include other agronomy meetings and extension publications such as the Miner Farm Report.

Next steps: The next steps for this research would be to set up a series of soil calibration experiments in the green house and in the field. By including multiple soil types varying in P fertility and soil properties, critical levels for both STP-ICP and STP-Color could be developed. In addition, laboratory incubations and field experiments should be developed to characterize organic P and the hydrolysis of organic P (e.g., conversion of organic P to orthophosphate). This work will ultimately lead to improved analytical methods for accounting for the mineralization of organic P in NNY soils.

Acknowledgments: We would like to thank the Northern New York Agricultural Development Program for funding this research.

Reports and/or articles: Results from this project have not been published elsewhere.

Person(s) to contact for more information: Eric Young, Miner Institute.

References

- Mallarino, A.P. 2003. Field calibration for corn of the Mehlich-3 soil phosphorus test with colorimetric and inductively coupled plasma spectroscopy determination methods. *Soil Sci. Soc. Am. J.* 67:1928–1934.
- Ketterings, Q.M., C. Miyamoto, R.R. Mathur, K. Dietzel, and S. Gami. 2011. A comparison of soil sulfur extraction methods. *Soil Sci. Soc. Am. J.* 75:1578-1583.
- Pierzynski G.M., H. Zhang, A. Wolf, P.J.A. Kleinman, A. Mallarino, and D. Sullivan. 2005 Phosphorus determination in waters and extracts of soils and by-products: Inductively-coupled plasma spectrometry versus colorimetric procedures. SERA-17 Policy Workgroup Paper [Online].
http://www.sera17.ext.vt.edu/Documents/P_Analysis_Comparisons.pdf

Appendix

Table 1. Summary statistics for soil test variables and soil test P (STP) measured by ICP and colorimetric procedures.

Soil test variable	N	Mean	SD†	Minimum	Maximum
pH	244	6.3	0.5	4.4	7.6
Organic matter (%)	244	3.6	1.2	1.1	7.5
K (lb/ac)	244	148	98	44	695
Mg (lb/ac)	244	420	346	61	1960
Ca (lb/ac)	244	3319	2342	593	31108
Al (lb/ac)	244	81	110	5	709
Fe (lb/ac)	244	12	15	1.9	154
Mn (lb/ac)	243	14	6	3.3	44
Zn (lb/ac)	244	2	1.5	0.4	11.3
STP-ICP§ (lb/ac)	244	18	21	2.5	195
STP-Color‡ (lb/ac)	244	15	21	1.4	192
STP-ICP - STP-Color†† (lb/ac)	244	2.5	1.5	0	12.9
STP-ICP : STP-Color	244	1.4	0.4	0.92	3.44

† Standard deviation

§ Soil test P measured by ICP

‡ Soil test P measured by molybdate colorimetry

†† Numeric difference between STP measured by ICP and colorimetry

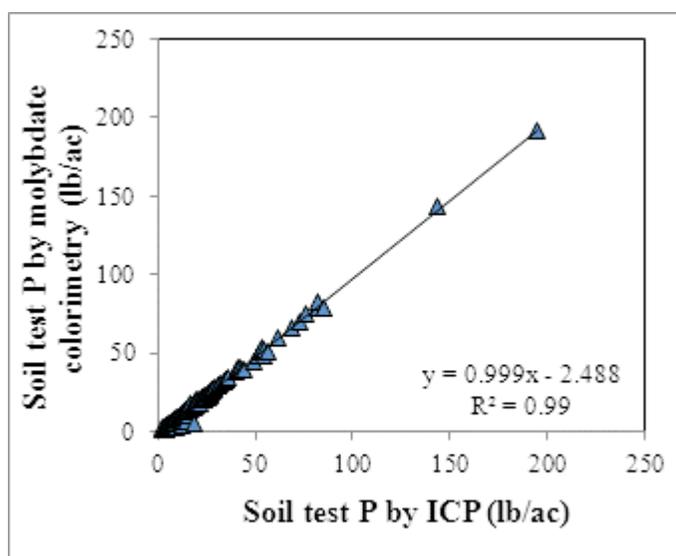


Figure 1. Relationship between STP-Color and STP-ICP and STP-Color for all samples ($n = 244$).

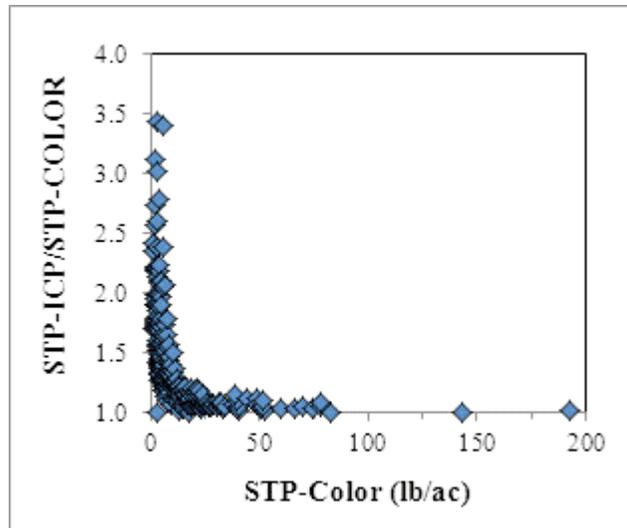


Figure 2. Relationship between STP-Color and STP-ICP for all samples.

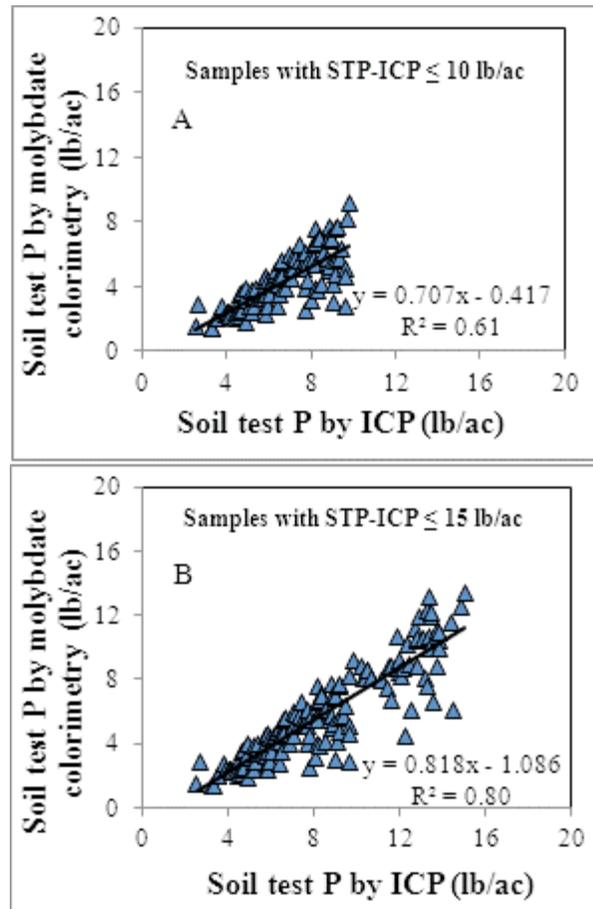


Figure 3. Relationship between STP-ICP and STP-Color for samples with an STP-ICP \leq 10 lb/ac (A) and for samples with and STP-ICP level of \leq 15 lb/ac (B).

Table 2. Summary of stepwise multiple linear regression statistics. The numeric difference between STP-ICP and STP-Color was used as the dependent variable and pH, organic matter, Al, Ca, Fe, K, Mg, Mn, and Zn were the set if independent variables.

Variable	Partial R-Square	Full model R-Square	F Value	P
Al	0.359	0.359	123.0	<.0001
Organic matter	0.170	0.529	29.1	<.0001
Mn	0.034	0.563	11.8	<.0001
pH	0.013	0.576	6.3	0.0067

Table 3. Percent agreement between ICP and colorimetric procedure for classifying samples into New York STP categories.

NY soil test P category	STP range (lb/ac)	% Agreement between ICP and Color methods
Very low	<1	-
Low	1-3	16
Medium	4-8	57
High	9-39	99
Very High	>40	100