THE INTERNATIONAL SOCIETY OF PRECISION AGRICULTURE PRESENTS THE
13th INTERNATIONAL CONFERENCE ON
PRECISION AGRICULTURE
July 31-August 4, 2016 • St. Louis, Missouri USA

Should one phosphorus extraction method be used for VRT phosphorus recommendation in the southern Great Plains?

D.B. Arnall[1], E.B. Rutter[1], P. Watkins[1], J. Warren[1], C. Penn[1], S. Phillips[2]

[1]Plant and Soil Sciences Department, Oklahoma State University, Stillwater OK.
[2]Internation Plant Nutrition Institute, Norcross AL

A paper from the Proceedings of the
13th International Conference on Precision Agriculture
July 31 – August 4, 2016
St. Louis, Missouri, USA

Abstract.
Winter Wheat has been produced throughout the southern Great Plains for over 100 years. In most cases this continuous production of mono-culture lower value wheat crop has led to the neglect of the soils, one such soil property is soil pH. In an area dominated by eroded soils and short term leases, Land-Grant University wheat breeders have created lines of winter wheat which are aluminum tolerant to increase production in low productive soils. Now the fields in this region can have very high degree of variation in soil pH levels and available aluminum content. Both of these aspects not only impact available phosphorus (P) levels but also the ability of phosphorus extraction methods to accurately determine plant available (P). This work has three objectives. First, evaluate the infield variation in soil test parameters of fields that have been grid sampled. Secondly, the impact of soil test pH on multiple soil test P extractants will be quantified. The first objective will be met by analyzing soil test results from 175 fields that have been sampled at a 1 to 2.8 hectare resolution. These fields will have been sampled by both Oklahoma State University researches and multiple private crop consultants. The second object will be met by utilizing six field trials previously established to evaluate the impact of soil pH and aluminum content on the grain yield of multiple crops. At each location the soil pH was manipulated to result in a range of pH's from 4.0 to 7.0. Soil samples will be collected from each plot, 36 per location, each sample will be analyzed for base cation content and P content using Mehlich 3, water soluble extraction procedures. The final objective is to determine if average variation of infield soil pH will cause incorrect recommendations in a variable rate fertilizer application program. Given the trends in the data and the effect soil-pH appears to have on Mehlich-3 and water extractions, it seems unlikely that using a single soil extraction method on soils of varying pH would yield recommendations that are at the scale of accuracy needed by needed by VRT producers.

Keywords.

Phosphorus, variable rate, soil testing, fertilizer recommendations, grid sampling, soil pH, Mehlich 3

Materials and Methods

Soil nutrient variablity

Grid soil sample data was solicited from Agricultural producers across the southern Great Plains were contacted via personal communications and social media methods. Cooperating producers shared there soil test reports and grid sampling summaries with researchers at Okalhoma State University most of the information was shared in form of pdf files. Data was transposed into two independent files stored on a secured server. One file consisted of field information, this included producers, service provider, state and county of field, field size, numbers of samples, sample resolution, and soil types (when available) within each field. The second file contained the individual sample soil test data, state and county. Within this file no producer information is available. To current date the data set included 178 fields which had a minimum of five soil samples. Field size varied from 6 to 49 hectares. Data was analyzed using R version 3.4.

Soil pH impact on Phosphorus extration values.

Site Description and Preparation

Four previously established field trials were used in this study to determine the impact of soil pH on various soil-P extraction methods. Field trials were carried out on a variety of soil types including a Dale silt loam (Fine-silty, mixed, superactive, thermic Pachic Haplustolls) at the South Central Agricultural Research Station in Chickasha, OK, an Easpur loam (Fine-loamy, mixed, superactive, thermic Fluventic Haplustolls) at the OSU Agronomy Research Station in Stillwater, OK, a Pond Creek silt loam (Fine-silty, mixed, superactive, thermic Pachic Argiustolls) at the North Central Research Station in Lahoma, OK, and a Teller loam (Fine-loamy, mixed, active, thermic Udic Argiustolls) in Perkins, OK. Trials in Chickasha and Stillwater, OK were arranged as a randomized complete block design with 6 treatments and 3 replications. Plots were 7.6-m long by 7.6-m wide and separated by a 1.5-m alley. Trials in Perkins and Lahoma were arranged in a randomized complete block design with 12 treatments and 3 replications. Plots were 7.6-m long by 3.8-m wide and separated by a 1.5-m alley.

Hydrated lime ($Ca(OH)_2$) and aluminum sulfate ($Al_2(SO_4)_3$) were applied to each plot to obtain target soil pH. The amount of material needed to reach a given target soil pH was determined with a laboratory experiment conducted in 2012 to develop a response curve to the soil of each location. In this approach, composite soil samples were collected from both experimental sites to characterize initial soil pH using a combination pH electrode in a 1:1 soil/deionized water suspension. Subsamples weighing 500 g were taken from each composite sample and mixed with five incremental rates of $Al_2(SO_4)_3$ and $Ca(OH)_2$. The samples were then wetted and, after two, three, and four weeks, soil pH of each subsample was measured. The resultant relationship between pH values and $Ca(OH)_2$ and $Al_2(SO_4)_3$ was used to produce response curves for each study location from which the amount of $Ca(OH)_2$ and $Al_2(SO_4)_3$ needed to achieve a target soil pH was determined. Hydrated lime was applied to raise or $Al_2(SO_4)_3$ was used to lower actual pH to the target pH according to initial soil pH values. Treatments were applied a few months prior to planting and plots were cultivated to incorporate the amendment products down to approximately 20 cm depth, which represents the typical surface acidic layer depth in Oklahoma. Initial soil fertility and amount of amendment needed to change soil pH by a unit for both locations are shown in Table x.

Soil pH

A composite soil sample consisting of approximately 15 soil cores 0 – 15 cm depth was taken from the trial areas before the establishment of the study for the evaluation of initial conditions, and $Ca(OH)_2$ and $Al2(SO_4)_3$ were applied to main plots prior to the first year of the study according to results from this analysis. To determine soil pH achieved after amendment application, composite samples were collected from each main plot June 2013, June 2014, and June 2015 same day wheat was harvested. A total of 108 composite soil samples were collected from the study sites over a 3-yr period. Samples were oven-dried at 65°C for 24 h and ground to pass a 2-mm sieve. These samples were stored in a climate controlled environment at 22°C, and soil pH was evaluated in February 2016. Soil pH was evaluated using a combination pH meter and 1:1 ratio of soil/deionized water. A 15g (+- 0.01-g) sample of soil from each plot was mixed with 15 mL (+- 0.01-mL) of deionized water (18.2 MOhm/cm). Results shown in Table x+1.

Mehlich 3

Soil nutrient availability was determined using a Mehlich 3 soil test for each plot. A 2.00-g (+-0.01g) sample from each plot was mixed with 20.00 mL (+-0.01 mL) of Mehlich 3 solution, yielding a 1:10 ratio of soil/extractant solution. These samples were then shaken at 200 excursions per minute (epm) for 5 minutes and then filtered through Whatman No. 2 filter paper. Resultant filtrate was then analyzed using inductively coupled argon plasma emission spectroscopy (ICAP). Subsequent soil test-P, Al, Fe, Mn, Ca, Mg, K, Zn, Cu, and S are shown in Figure x.

Water Soluble Orthophosphate

Soluble-P was determined for each sample using a water extraction. A 2.00-g (+-0.01-g) sample of soil was mixed with 20.00-ml (+-0.01-ml) of deionized water (18.2 MOhm/cm). Samples were then shaken at 100 epm for 1 hour, and filtered through Whatman No. 2 filter paper. The filtrate was then centrifuged for 15 minutes at 2000 rpm and decanted. The resulting liquid was analyzed for orthophosphate with ion chromatography (880 nm) and flow injection analysis on a Lachat. Results shown in figure x+1

Data Analysis

Soil extraction data were analyzed by location, as each site represents a different soil evolved from different parent material and under different environmental conditions. Simple linear regressions relating soil-P to soil-pH were performed in R version 3.4. Results shown by location in Figures 1-

Results

Fields utilized in this data were located in Kansas and Oklahoma. Dataset included twenty fields from three counties in Kansas and 158 fields from 19 counties in Oklahoma. On the average fields had adequate soil pH, phosphorus, and potassium levels, see Table 1. In Table 1 the phosphorus value contains both Mehlich 3 and Bray 1 values. Both of these extractant had average values within 2 ppm of each other. Due to some labs not providing either Mehlich 3 or Bray 1 the phosphorus dataset only includes 155 fields. Of the phosphorus samples utilized in the data set 50 were from Mehlich 3 extractions while 105 had Bray 1 phosphorus values.

Table 1. Results of the grid sample data set. Data set includes 178 fields. Values represent average values recorded across all fields.

	Average	Range	Min	Max
Soil pH	6.12	1.77	5.23	7.01
Phosphorus	28	52	2	54
Potassium	197	180	107	287
Sulfur	15	24	3	27
OM	1.9	1.2	1.3	2.5

Table 2. Linear regression analysis of the Mehlich 3 phosphorus extraction results across all locations.

	Dependent variable:			
	Soil-P			
	Stillwater	Chickasha	Lahoma	Perkins
poly(pH, degree = 2)1	-41.644***	-25.091***	-40.969***	-16.885**
	(5.727)	(2.712)	(6.719)	(6.195)
poly(pH, degree = 2)2	23.306***	9.081***	9.745	9.366
	(5.727)	(2.712)	(6.719)	(6.195)
Constant	39.879***	22.616***	47.591***	35.905***
	(0.727)	(0.353)	(1.120)	(1.032)
Observations	62	59	36	36
R^2	0.541	0.633	0.543	0.227
Adjusted R^2	0.525	0.620	0.516	0.181
Residual Std. Error	5.727 (df = 59)	2.712 (df = 56)	6.719 (df = 33)	6.195 (df = 33)
F Statistic	34.724*** (df = 2; 59)	48.391*** (df = 2; 56)	19.641*** (df = 2; 33)	4.858** (df = 2; 33)
Note:				$^{*}p^{<0.1; >**}p^{<0.05; >***}p<0.01$

Figure 3. Linear regression analysis of the water soluble phosphorus extraction results across all locations.

	Dependent variable:			
	Soil-P			
	Stillwater	Chickasha	Lahoma	Perkins
poly(pH, degree = 2)1	1.269	2.975***	3.091***	-0.123
	(1.378)	(0.447)	(0.683)	(0.459)
poly(pH, degree = 2)2	-6.322***	-2.798***	-1.502**	-0.845*
	(1.378)	(0.447)	(0.683)	(0.459)
Constant	3.415***	2.263***	1.946***	1.309***
	(0.191)	(0.059)	(0.117)	(0.078)
Observations	52	57	34	35
R^2	0.309	0.607	0.450	0.098
Adjusted R^2	0.281	0.593	0.414	0.041
Residual Std. Error	1.378 (df = 49)	0.447 (df = 54)	0.683 (df = 31)	0.459 (df = 32)
F Statistic	10.948*** (df = 2; 49)	41.716*** (df = 2; 54)	12.664*** (df = 2; 31)	1.734 (df = 2; 32)
Note:				$^{*}p^{<0.1; >**}p^{<0.05; >***}p<0.01$

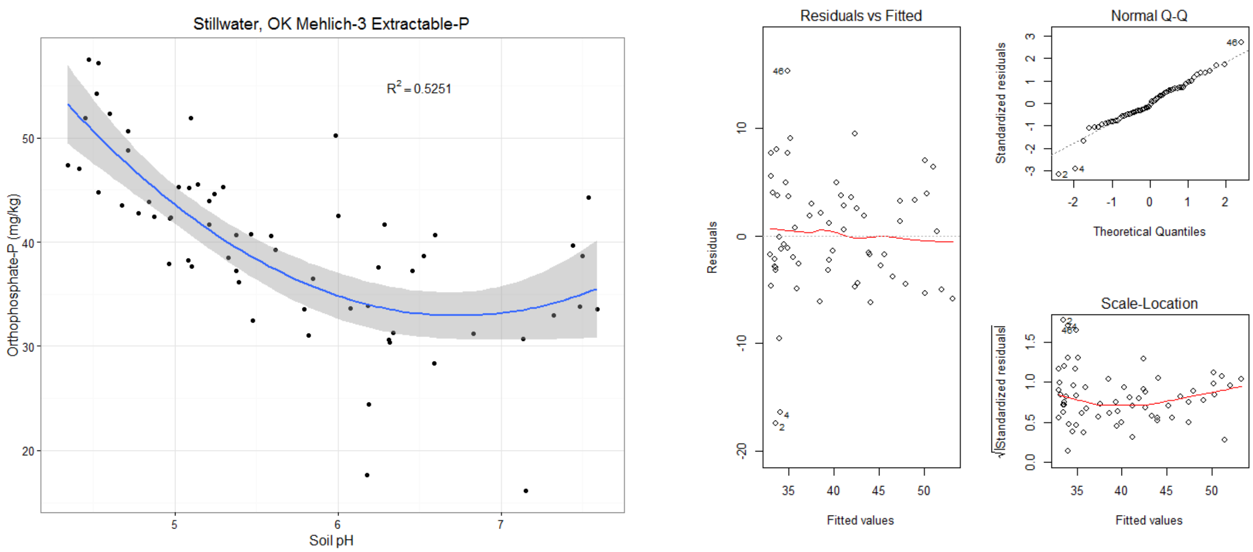

Fig 1. Linear regression analysis for the Stillwater, OK Mehlich-3 results show a curvilinear P-response to changes in soil pH, with generally higher P concentrations at lower pH values. Residual and Normality plots show no obvious signs of invalid regression assumptions.

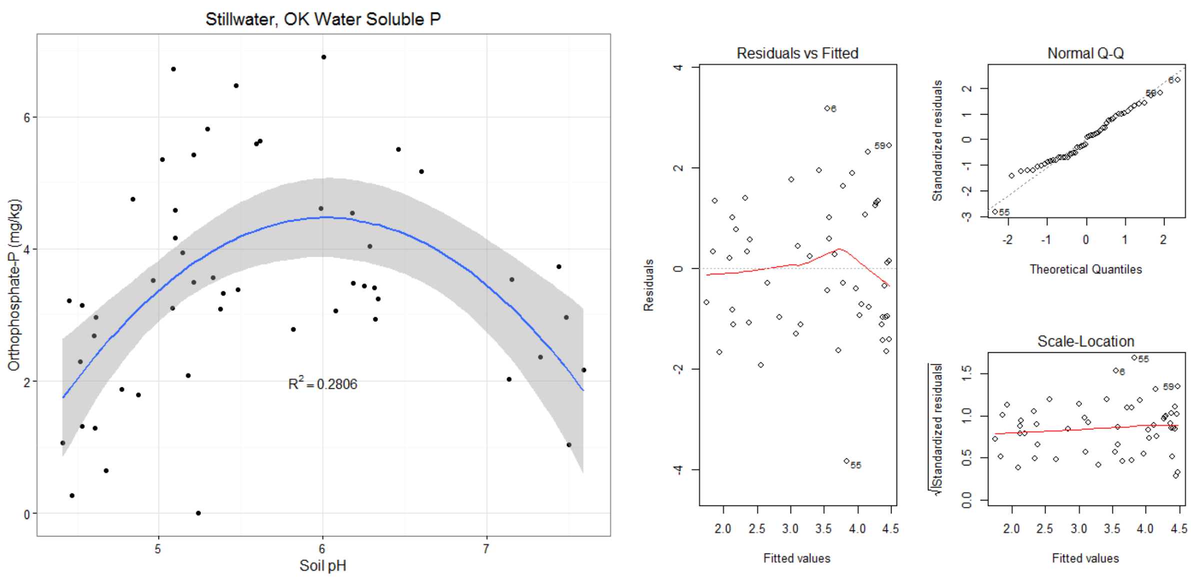

Fig 2. Linear regression analysis for the Stillwater, OK water soluble-P results show a curvilinear P-response to changes in soil pH, with generally lower P concentrations at lower pH values.

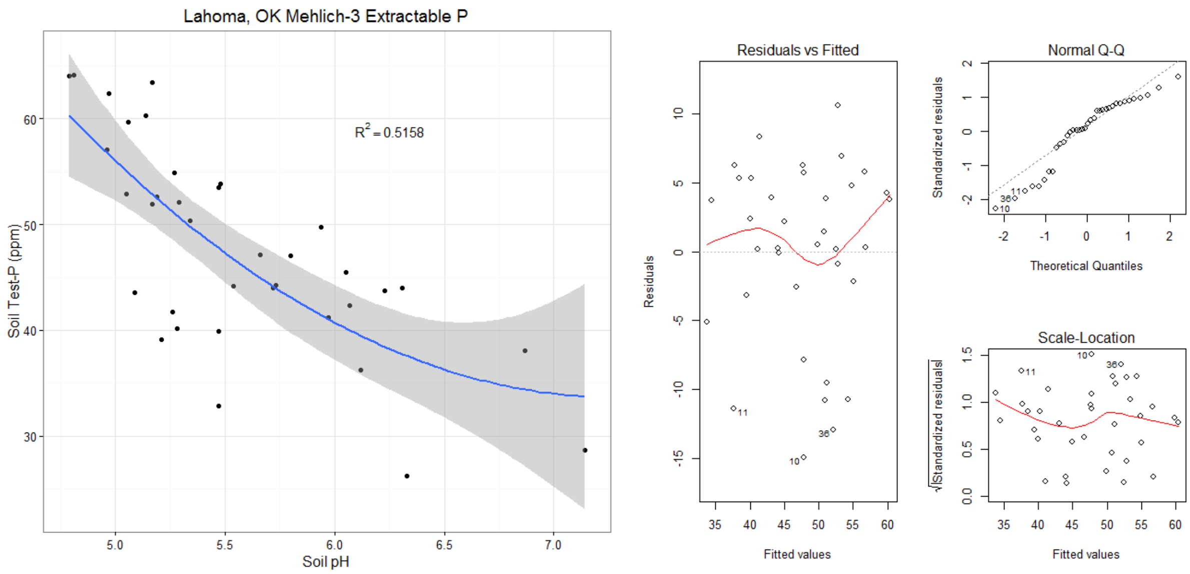

Fig 3. Linear regression analysis for the Lahoma, OK Mehlich-3 results show a curvilinear P-response to changes in soil pH, with generally higher P concentrations at lower pH values. Residual and Normality plots are acceptable given the relatively small sample size and low number of data points in the neutral pH range.

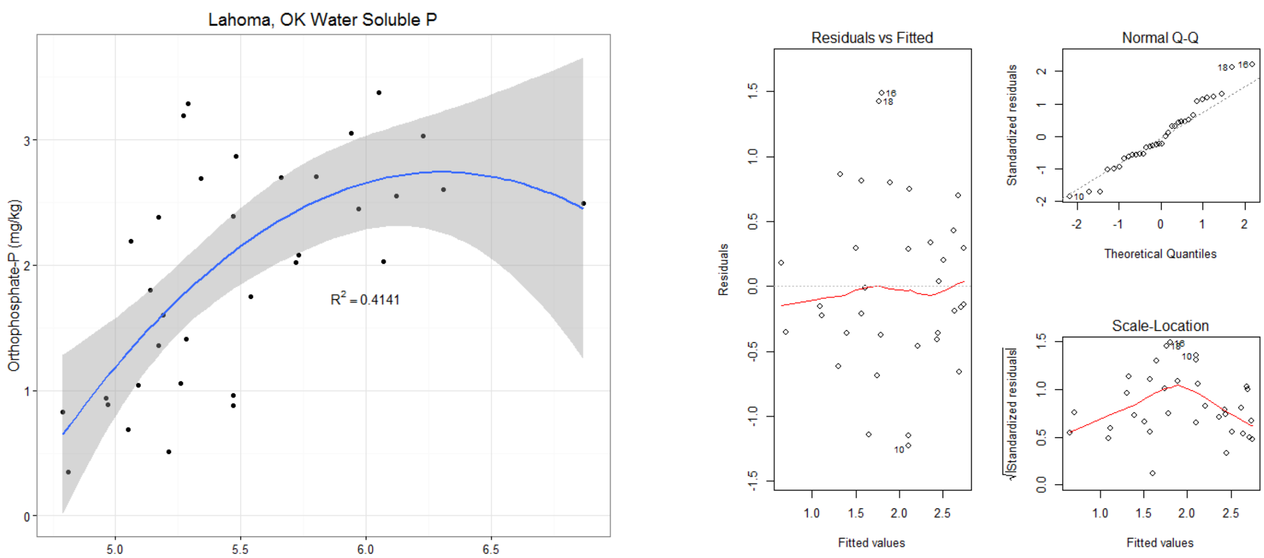

Fig 4. Linear regression analysis for the Perkins, OK Mehlich-3 results show a curvilinear P-response to changes in soil pH, with generally higher P concentrations at lower pH values. Residual and Normality plots are acceptable given the relatively small sample size and low number of data points in the neutral pH range.

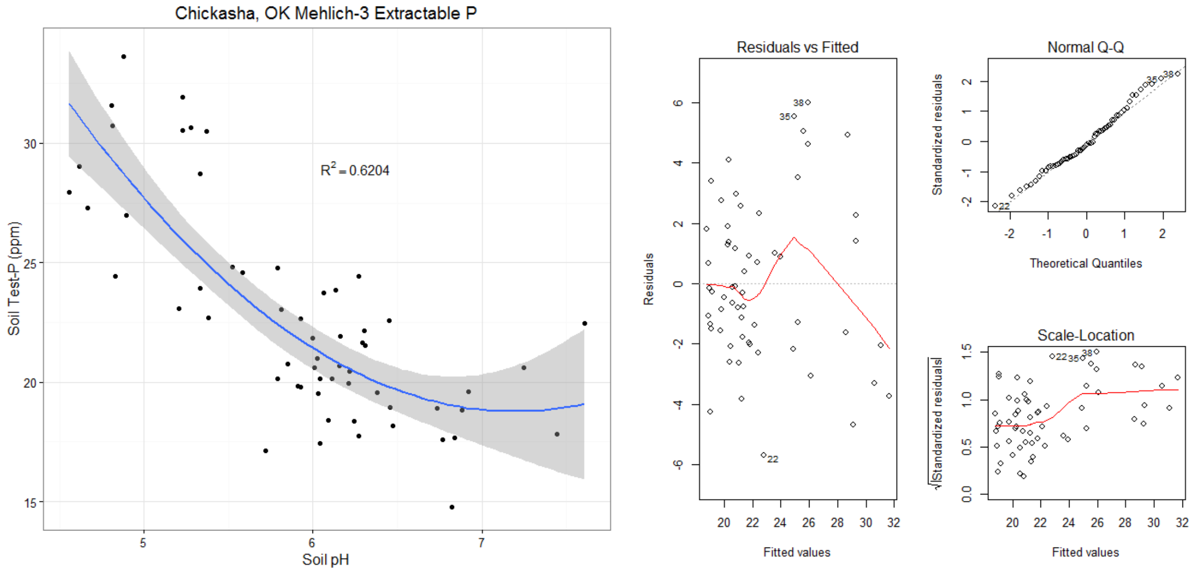

Fig 5. Linear regression analysis for the Chickasha, OK Mehlich-3 results show a curvilinear P-response to changes in soil pH, with generally higher P concentrations at lower pH values. Residual and Normality plots show no obvious signs of invalid regression assumptions.

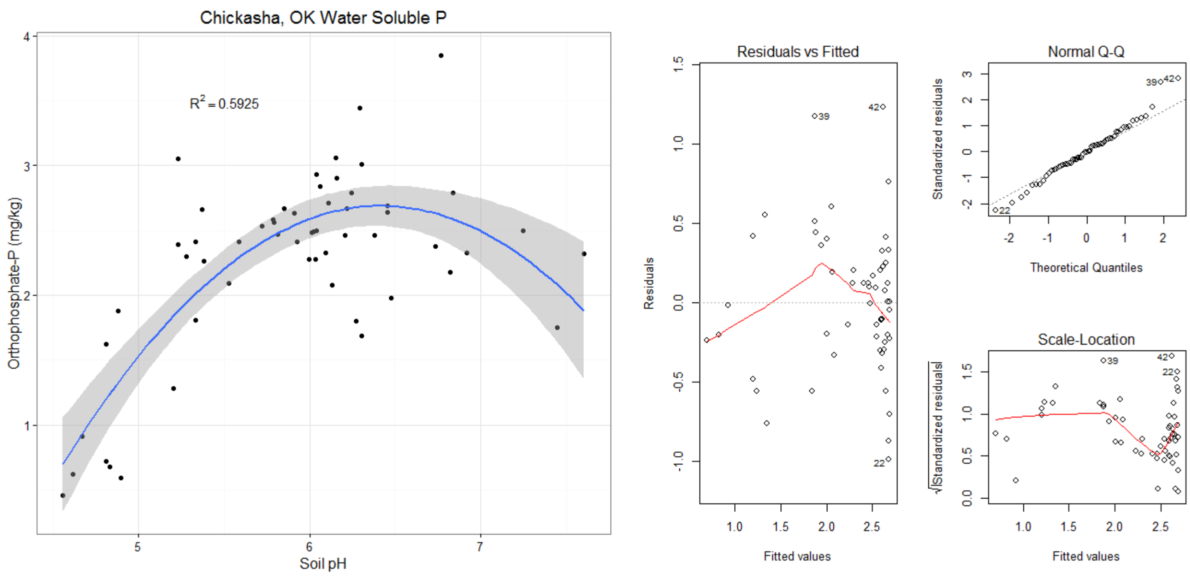

Fig 6. Linear regression analysis for the Perkins, OK Mehlich-3 results show a curvilinear P-response to changes in soil pH, with generally lower P concentrations at lower pH values.

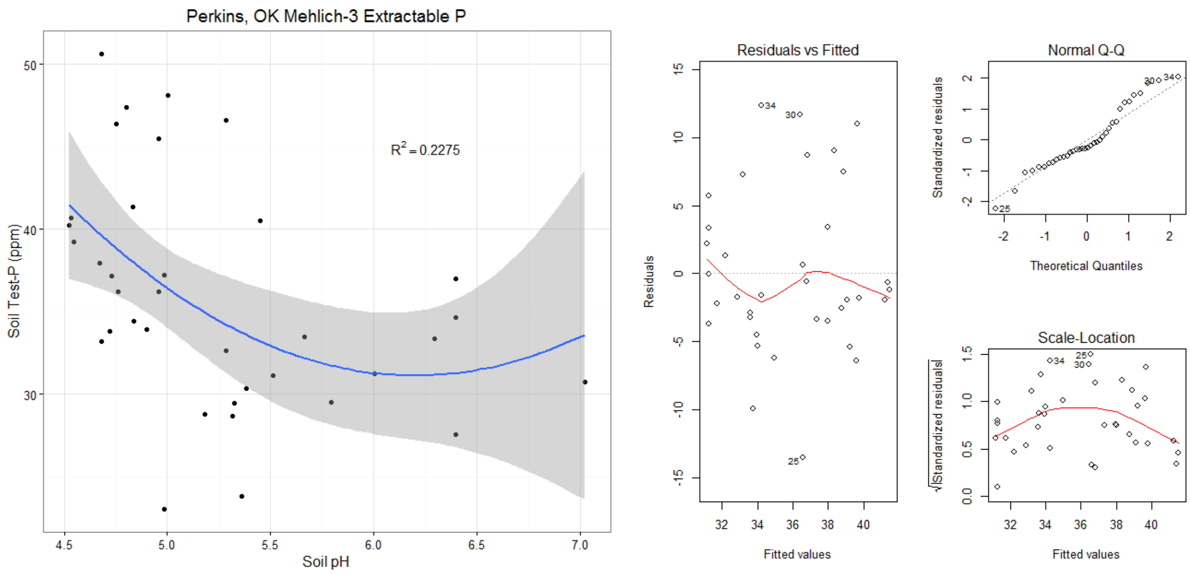

Fig 7. Linear regression analysis for the Perkins, OK Mehlich-3 results show a curvilinear P-response to changes in soil pH, with generally higher P concentrations at lower pH values. Residual and Normality plots are acceptable given the relatively small sample size and low number of data points in the neutral pH range.

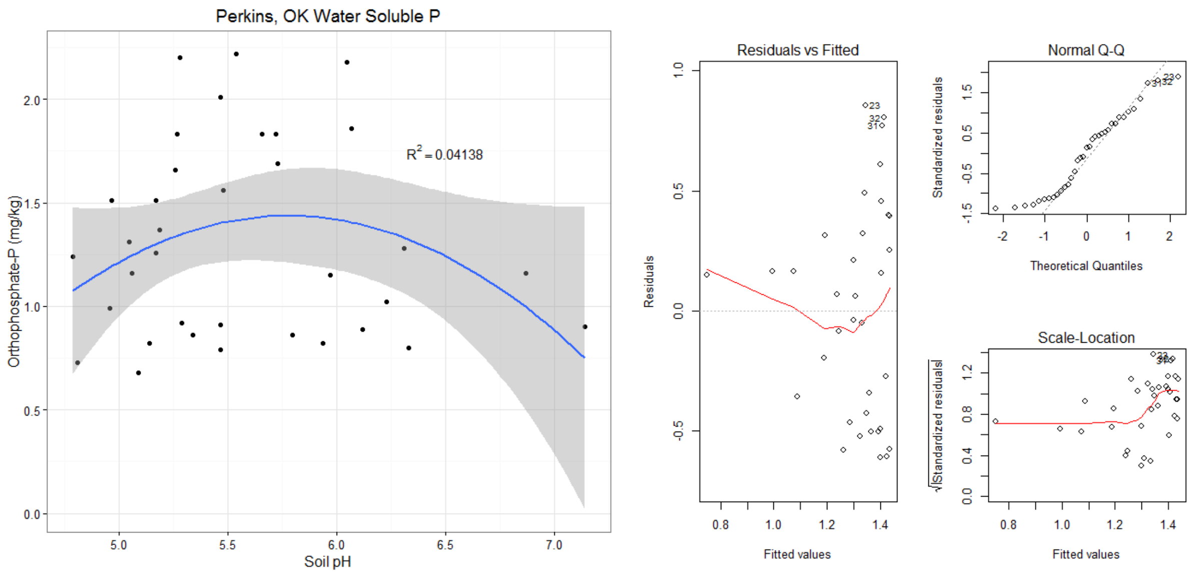

Fig 8. Linear regression analysis for the Perkins, OK Mehlich-3 results show a curvilinear P-response to changes in soil pH, with generally higher P concentrations at lower pH values. Residual and Normality plots are problematic, as is the low value for the adjusted R2. This site needs further investigation as there appear to be two seperate trends in the data.

Conclusion or Summary

Knowledge of the magnitude of soil variability is not new. In fact the entire premise of precision agriculture is to address the spatial and temporal variability seen in agricultural production systems. This paper is not questioning whether or not current practices are better than past farm and field scale management strategies. This project does bring to question whether or not the technology has outpaced the soil science. Current phosphorus fertility recommendations are based upon high quality correlation calibration data. Unfortunately nationally this data set is decades old and often the original data has been lost to time. These original recommendations were also developed to be sufficient on a state wide basis. We are now taking this same soil testing and fertilizer recommendation approach and applying it on a higher often sub acre resolution.

Given that P recommendations should be based off of accurate available-P descriptions: an intensity factor (I) describing immediately available P. a quantity factor (Q) describing the size of the labile soil-P pool, a capacity factor (d(Q)/d(I)) which describes how well the soil system can buffer soluble-P concentrations with P removal, and ideally both rate and diffusion factors as well. Common soil extractions, such as Mehlich-3, Bray-1, etc., will likely provide good estimates of labile-P (Q), but ignore the intensity factor (I). On the other hand, water extractions likely provide a good estimate of immediately available P (I), but have no way to quantify the labile pool (Q). Given the trends in the data and the effect soil-pH appears to have on Mehlich-3 and water extractions, it seems unlikely that using a single soil extraction method on soils of varying pH would yield recommendations that are at the scale of accuracy needed by needed by VRT producers.

This project is still in its infancy and data and analysis is still being performed. It is not the expectation of the researchers that a solution can be derived from this data. It is the hopes that this work will provide rationale and direction so that more focus may be placed improving the recommendation strategies for variable rate phosphorus.

Acknowledgements

Support from the Oklahoma Field and Research Service Units, Oklahoma State Cooperative Extension Service, and the International Plant Nutrition Institute.

References

F.J. Stevenson and M.A. Cole (1999). Cycles of Soil: Carbon, Nitrogen, Phosphorus, Sulfur, Micronutrients. New York,NY: John Wiley & Sons, INC