COLORADO

# *Variability of Phosphorus Over Landscapes and Dryland Winter Wheat Yields*

By R.A. Ortega, D.G. Westfall and G.A. Peterson

The use of variable rate fertilizer technology (VRT) is receiving considerable attention. It offers potential benefit to the economics of agricultural production and potential minimization of adverse environmental impacts caused by improper rates of fertilizers and agricultural chemicals in general.

Because of the spatially continuous nature of landscapes and soil formation processes, it is not unreasonable to expect that soil measurements taken in proximity to each other would be related to themselves and to variations of other parameters or properties of the landscape.

> Yield and yield response to fertilizer depend not only on soil nutrient level, but also on other growth limiting factors. In recent Colorado studies, soil test phosphorus (P) levels did not necessarily predict wheat yield response to P fertilizers. A "multivariate" approach is necessary to predict yield response.

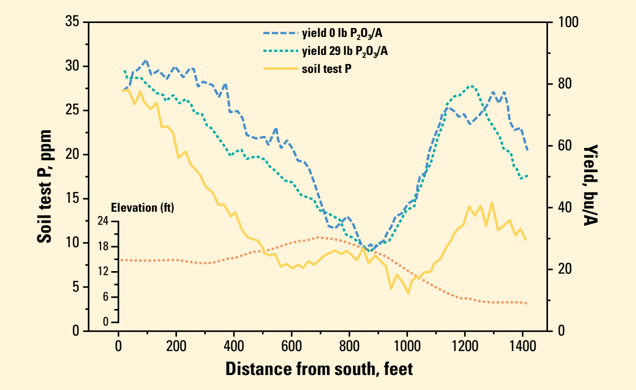


**Figure 1.** The variability in $NaHCO_3$-P and yield of dryland winter wheat over the Sterling landscape. Lines represent kriged values.

We have been conducting research to quantify the spatial variability of soil test P, other selected soil properties, and winter wheat grain yields over typical dryland landscapes in the central Great Plains.

## Field Study

This experiment was conducted at two field locations in eastern Colorado – Sterling and Stratton. Dryland winter wheat, fertilized with five P rates (0, 12, 23, 34, and 46 lb $P_2O_5$/A, band applied as 10-34-0 with the seed) was planted in parallel strips over the landscapes. At Stratton only two P rates (0 and 46 lb $P_2O_5$/A) were used. For nitrogen (N) fertilization, 46 lb N/A as UAN solution was applied to all treatments. The elevation differences within the landscapes were 18 and 12 ft. at Sterling and Stratton, respectively. This topographic relief is typical of the central Great Plains. We soil sampled and determined yields at 73 and 35 positions (every 20 ft.) from the Sterling and Stratton landscapes, respectively.

## Variability of Soil Characteristics (0-4 inches)

The $NaHCO_3$-P concentrations varied from 1 to 31 parts per million (ppm), shown in **Figure 1**. The $CaCO_3$ varied from zero to almost 2 percent C, pH from 5.7 to 8.5 (**Figure 2**). Organic matter varied from 1.19 to 2.03 percent while inorganic N ($NO_3$-N plus $NH_4$-N) varied from 12 to 32 ppm across the landscape at the Sterling location (**Figure 3**). Positions with low P levels also had high levels of $CaCO_3$, high pH, and low organic matter. Similar variations in soil properties were found at the Stratton location. The range (distance at which samples become independent) was 590 ft. for inorganic N and less than 531 ft. for all other soil properties. All soil properties showed high spatial dependency (positive autocorrelation), which allowed kriging models to accurately predict our variables.

## Yield Variability

Dryland winter wheat yields varied from 14 to 97 bu/A, depending on landscape position and P rate at Sterling (**Figure 1**). Grain yield showed a strong spatial dependency which resulted in high coefficients of determination (R2 = 0.88 to 0.92) using kriging models. The range of spatial dependency for yield averaged 304 ft., somewhat similar to those other soil properties.

At the Stratton location (data not shown), wheat grain yields varied from 17 to 90 bu/A. Yields showed a high spatial autocorrelation, therefore kriging models predicted our data very well. The average range of spatial dependency for grain yield was 217 ft.

Grain yield at 42 percent of the sampling locations along the Sterling landscape responded to P fertilization. Seventy-two percent of all these positions were below 14 ppm $NaHCO_3$-P [the current P critical level (CL) for Colorado.] However only 38 percent of those below the CL responded to P application (**Figure 1**). Similarly, 28 percent were above the CL and 50 percent of those above the CL responded to P fertilization. Similar results were observed at Stratton. On the average, the current CL that divides responsive from non-responsive soils failed 59 percent of the time.

## The Big Question

"Why didn't soil test P more accurately predict yield response to P fertilizer?" These results point out an important, and long understood, relationship but one that many of us working in soil fertility often forget or disregard. That is, plant response is often limited by factors other than nutrient availability. In our studies, the response to P fertilizer, and ultimately dryland winter wheat grain yields, did not depend solely on the P soil test level, but several other growth limiting factors. For example, at the Sterling location, some low yielding positions in the land-

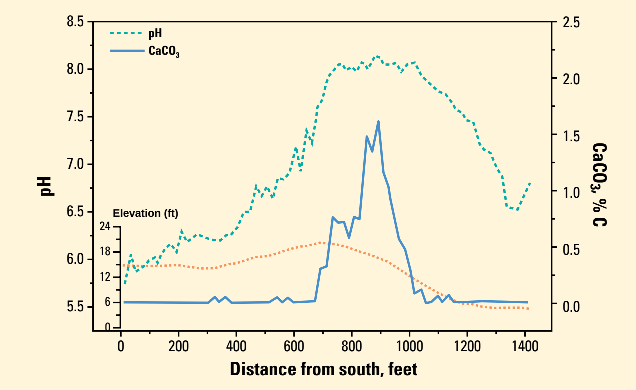


**Figure 2.** The variability in soil pH and free lime ($CaCO_3$) over the Sterling landscape.
Lines represent kriged values.

scape did not respond to P fertilization, although their P levels for the positions were very low (800 to 1,000 ft. in landscape, **Figure 1**). These positions had low organic matter and residual soil N levels, contained free lime and were highly eroded landscape positions. Over the years most of the topsoil had been lost by erosion. Therefore, shallow topsoil and low water holding capacity were probably the most limiting growth factors. No rate of fertilizer P would result in an increase in grain yield even though soil test-P levels were very low.

## Relationship Between Winter Wheat Grain Yields and Soil Properties

Grain yield always correlated with all measured soil properties, either positively or negatively. In other words, the soil properties we measured explained only part of the yield variation, but not all of it. If we used only one single variable (for example $NaHCO_3$-P) to predict yield and response to fertilizer application, this model often failed. A multivariate approach must be used to overcome this problem because other factors are limiting yields.

We performed a principal component analysis on both sites to better describe and separate the different landscape positions by using "indices" representing an integration of soil properties. At Sterling and Stratton, the principal component 1 ("soil index 1") explained 70 and 94 percent of the total yield variance, respectively. Soil organic matter and organic N, extractable-P, and moisture influenced the principal component 1 value positively in contrast to the negative influence of lime content and pH. Similar results were obtained for Stratton. This multivariate approach was successful in predicting yield response over the landscape with soil test-P being only one component of the response model. This points out the importance of considering all the production factors we recognize as yield limiting, when using VRT systems. A single soil test measurement will not give consistent, reliable results.

## Conclusions

Soil properties and dryland winter wheat yields varied widely across landscapes. Most measured variables were highly autocorrelated, which allowed kriging models to predict soil parameters and yields accurately.

Response to P fertilization was erratic in both landscapes. Soil test-P levels did not necessarily predict response to P fertilizer. Other growth limiting factors often controlled response to P fertilizer.

All measured soil properties were highly correlated with yields. Yields were a function of soil properties that can be represented by principal component analysis, i.e., considering all the factors we recognize as yield limiting in a particular field.

Our results demonstrate that a multivariate

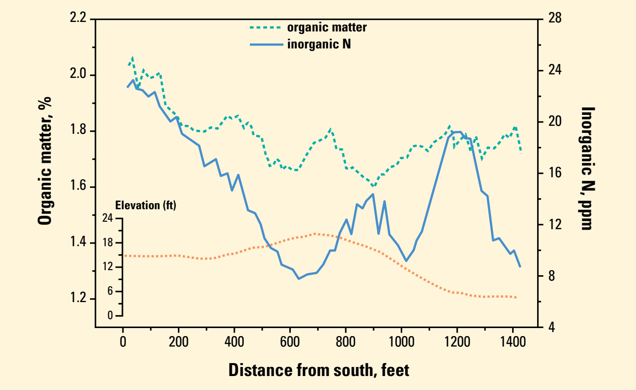


**Figure 3.** The variability in soil organic matter (OM) and residual soil inorganic N ($NO_3$-N+$NH_4$-N) over the Sterling landscape. Lines represent kriged values.

approach to nutrient recommendations is required, since yields and yield response to fertilizer are not only dependent on the soil nutrient level but other growth limiting factors. Other production parameters need to be considered when making VRT fertilizer recommendations based on soil test level. The big question is: "What are these factors and can we control or modify them"? Until the controlling "soil factors" are identified and understood, maximum benefit of VRT is not possible and inconsistent results of VRT will be obtained. BC

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# E.T. York Honored as a "Great Floridian"

Dr. E.T. York, chancellor emeritus of Florida's state university system and a distinguished service professor emeritus at the University of Florida's (UF) Institute of Food and Agricultural Sciences, has been designated as a "Great Floridian" by Florida History Associates, the direct support organization of the Museum of Florida History in Tallahassee. This honor has been bestowed on only 11 other Floridians who have made notable contributions in shaping the state of Florida.

A native of Alabama, Dr. York joined UF in 1963, where he served as vice president for agricultural affairs, executive vice president and interim president. In 1975, he became chancellor of Florida's state university system for five years, retiring early to pursue his long-term interest in global hunger and Third World development.

Included among Dr. York's numerous awards are the President's Voluntary Action Citation presented by President Reagan; the "Service Above Self Award" of Rotary International, the highest recognition accorded a Rotarian; and a citation issued by the National Association of State Universities and Land Grant Colleges recognizing "his inspired leadership in mobilizing the resources of our universities in the ongoing struggle against poverty and hunger throughout the world."

He was appointed to prominent advisory positions by Presidents Kennedy, Johnson, Nixon, Carter, Ford and Reagan, by various foreign governments and by a number of U.S. governmental agencies. Dr. York received his bachelor's degree in agricultural science and his master's degree in soils/agronomy, both from Auburn University, and his Ph.D. in soils from Cornell University.

Dr. York was Eastern Director of the American Potash Institute in the late 1950s and served on the board of directors of the Foundation for Agronomic Research (FAR) in the 1980s and early 1990s. All of us at PPI and FAR proudly congratulate him for being named a "Great Floridian". BC