OKLAHOMA

Expectations of Precision Phosphate Management

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Variability of Available Soil Phosphate

Among-Field Variability. Soil test P (STP) varies greatly within and among fields. **Figure 1** shows the variability of STP among 50 wheat fields tested from a major wheat growing county (Garfield) in Oklahoma in 1996. Results are from composite soil samples representing the surface soil (0 to 6 inches) of fields averaging 80 acres in size. It is not surprising that variability is quite great among fields in a county with 450,000 acres of wheat. This variability is a result of large scale differences in soil types, past production levels and fertilizer use.

Several questions accompany the advent of precision agriculture in crop production...how variable are fields; what happens when this variability is treated? This article examines variability of available soil phosphorus (P) and some of the expected outcomes of its treatment.

Within-Field Variability. Variation in STP on a smaller scale is illustrated in **Figure 2a**, which shows STP values for 50 samples taken from 10 x 10 foot plots along a 500 foot transect in a 50 x 500 foot area used for correlating STP and wheat forage yield. Although not as great as the among-field variability, within-field variability in this small area included a 4-fold difference between the lowest and highest value.

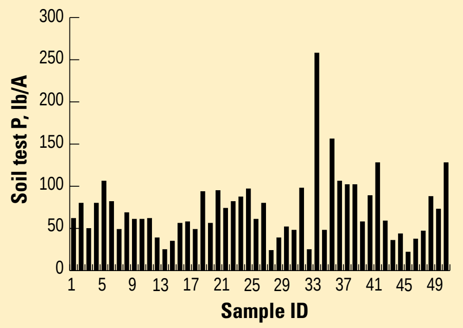

Figure 1. Soil test P variability among 50 soil tests for wheat in Garfield County, Oklahoma (1996).

Treating Field Variability

Variable Rate. It is well established and accepted that STP variability among fields will diminish if high testing fields receive less, or no fertilizer P, and low testing fields receive more, relative to past fertilizer P inputs. Similarly, if areas within a field are fertilized in relation to variable STP values, variability might decrease in time. This hypothesis was tested by applying a response model to the data in **Figure 2a**.

The model uses soil test values which have been calibrated on a percent sufficiency basis, whereby yields at each soil test level were expressed as a percent of the maximum yield obtained when adequate, but not excessive, fertilizer P was applied. For example, the soil test value of 20 is 80 percent sufficient. Without P fertilizer, the predicted yield would be 80 percent of the 40 bu/A yield goal (0.80 x 40 = 32 bushels). The soil test calibration

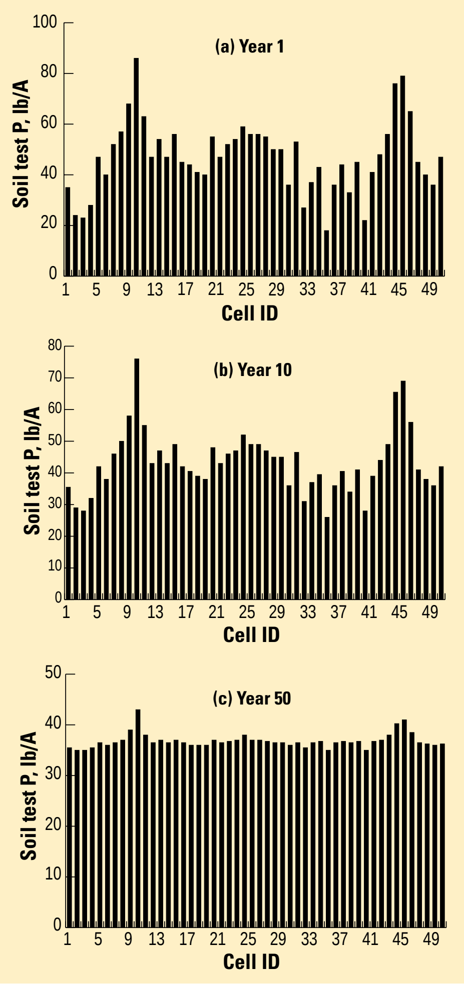

Figure 2. Effect of variable rate treatment on field variability with time.

identifies a rate of 40 lb/A P_2O_5 broadcast-incorporated would be needed to correct the deficiency for one year.

We then use the model to calculate wheat yield, P removal, and change in STP for each 10 x 10 foot plot as if it had been fertilized and with a wheat response according to local STP calibration (Mehlich III or Bray P-1) for a projected 50 year period. The yield potential was assumed to be constant across the field at 40 bu/A and P the only yield limiting factor (acknowledged unrealistic assumptions). Grain P concentration was assumed at 0.4 percent for calculating P removal. STP was assumed to decrease one unit for every 20 lb P_2O_5 removed by the crop in excess of fertilizer addition, and STP was assumed to increase one unit for every 20 lb P_2O_5 added to the soil in excess of crop removal.

Because grain harvest does not remove large quantities of P, and relatively small amounts of fertilizer P are required to correct the annual crop deficiency even in low STP areas, there is little change in STP variability the first 10 years (**Figure 2b**). After 20 to 30 years, most of the STP variability in the field has been removed, and after 50 years the levels of STP are almost constant across the field (**Figure 2c**).

These projections support the hypothesis that variable rate P fertilization, according to some measure of potentially available soil P, should reduce the need for variable rate applications.

Constant Rate. When a constant rate of P fertilizer is applied to a field made up of many areas that differ in available soil P, variability in STP for the field does not change over time. Using the same approach as for developing **Figure 2**, the effect over time of a constant 46 lb/A rate of P_2O_5 (100 lb/A of DAP is a common rate) was evaluated (**Figure 3**). This figure shows variability remains almost the same after 10 years.

Field Element Size. Of particular interest to the consideration of precision agriculture is the treatment resolution, or field element size. That is, how small should grids be to best identify variability in the field, and what is the smallest size that should be treated? To examine these questions, the response model was used to calculate projected wheat yields, P_2O_5 applied, and marginal profit associated with variable rate treatment for the 50 plots measuring 10 x 10 foot when a

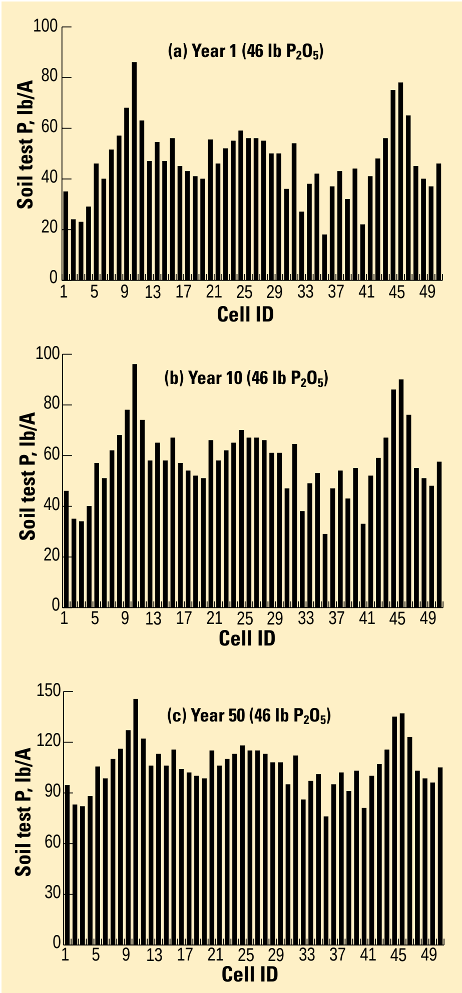

Figure 3. Effect of constant rate treatment on field variability with time.

constant P_2O_5 rate was applied to smaller and smaller sections of the field.

Initially the average STP of the 50 plots (47 lb/A) was used to identify a "field" rate of P_2O_5 to apply. Yield for the field was predicted by using the model to calculate response for each plot based on its STP value and summing these values. Yield without P_2O_5 addition was similarly calculated for estimating the marginal return from fertilizing. Next, the first 25 plots and the last 25 plots were treated as separate areas of the field, each receiving a constant P_2O_5 rate based on the average STP for the 25 plots involved. Smaller and smaller areas of the field were independently treated until finally each 10 x 10 foot plot was treated separately. Each time smaller groupings were considered, projections for the treated area (field element size) were made. Yield, P_2O_5 and marginal profit totals for the field were compared to that obtained when a single P_2O_5 rate was applied to all 50 plots. These results show that as the field element size decreases, there is a gradual and then rapid increase in total yield, P_2O_5, and profit (**Figure 4**).

Discussion and Conclusions

General. Crop yield and profit are maximized when the ability to treat smaller units increases to that size representing the smallest identifiably "different". That is, maximum economic yield (MEY), based on marginal profit from fertilizer, is achieved when the smallest variable unit is treated. This assumes costs of identifying and treating small variable units in a field are negligible compared to conventional approaches.

Among-Field Variability. When the above conclusion is applied to variability among fields, it indicates that when fields have different fertilizer needs they should be treated differently. Although this may seem clearly obvious, a survey of Garfield county wheat producers, participating in a free soil testing program, showed: 1) only 58 percent of the fields had been soil tested within the last three years; and 2) 67 percent of the participants treated the five fields they had tested the same, even though tests indicated large differences in fertilizer needs. Results illustrated in **Figure 4** also indicate that as more and more individual fields in a community (or fertilizer dealers retail area) are regularly soil tested and treated according to the soil test recommendations, there should be an increase in fertilizer use efficiency and farmer profit. If, on the average, fields in the community need fertilizer, then individual field treatment, rather than using a common fertilizer program for groups of fields, will result in increased sale of fertilizer.

Within-Field Variability. Variabil-ity of STP in fields has been shown to exist over distances of only a few feet (**Figure 2a** and other intensive soil sampling data). While identification of soil P deficiency by conventional means at this level of resolution may be cost prohibitive (435 soil tests per acre), separately soil testing large portions of a field that appear to be different based on visual observation of soil color, soil type, or crop yield, should be economical. Results in **Figure 4** were obtained by systematically reducing the treated area in half, without regard to whether a grouping of cells by STP level could be done. In many field situations, large areas can be logically identified for soil testing and fertilizing independently based on soil survey and yield monitor maps.

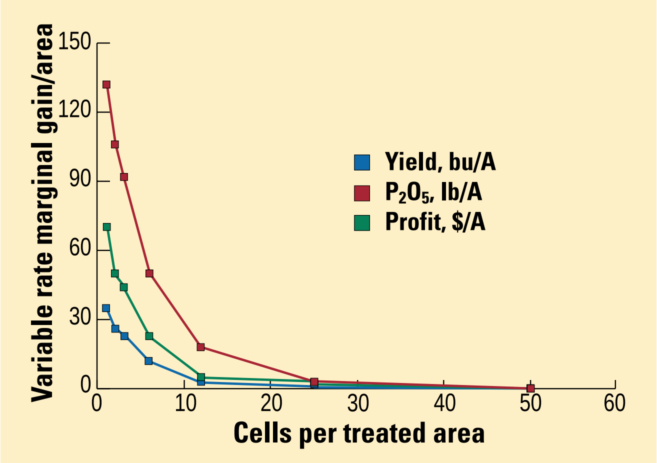

Figure 4. Relative effect of field element size on field yield, P_2O_5 used, and marginal profit.

High resolution field element size, such as 10 x 10 feet, may be economical to manage in precision farming when nutrient deficiencies can be identified at low cost, such as with GPS-coupled, sensor-based mapping. When that is possible, it may be important to speed the transition of buildup and depletion shown in **Figure 2** by adding higher rates than required for annual correction of deficiencies. If uniformity could be achieved in five years, then a constant rate could be used. With this approach, costs associated with each application of variable rates could be minimized.

Finally, this treatment of data clearly shows farmers will benefit economically in relation to the extent to which they are able to detect and treat variable fertilizer needs on the land they manage. Until new technology replaces conventional soil testing, its value for increasing yields, farmer profits, and fertilizer use could not be more clear. BC

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