TENNESSEE

Site-Specific Nutrient Management: Variability in Cotton Yield Response and Soil Chemical Characteristics

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The physical and chemical properties of soils change over short distances. As a result, the soil's ability to produce crops can vary with location in a field. Conventional fertilizer management strategy relies on the premise that soil fertility and the production potential of a soil can be assessed over large areas. This strategy can result in fertilizer under-application to some areas of a field and fertilizer over-application to other areas. The consequences of both have economical as well as environmental repercussions.

Precision farming, or site-specific farming, can be defined as a management system with the flexibility to adjust agrochemical inputs to satisfy needs of specific areas in a field to achieve the soil's yield potential, rather than using uniform applications based on average field characteristics. With precision farming, producers have the ability to place crop nutrients where they are needed.

In 1996, a multi-disciplinary precision farming study was initiated at The University of Tennessee Agricultural Experiment Station in Milan, Tennessee. One of the goals of the study was to examine the variability in soil chemical properties in a cotton field and to relate nutrient variability to yield variability. The objective of this article is to illustrate, using selected soil chemical characteristics, the influence of soil sampling grid size on the estimated soil fertility levels of the field. Soil fertility data are also correlated with cotton yield to evaluate the feasibility of site-specific soil sampling.

Milan Study

A 5-acre, no-till cotton field located at the Milan Experiment Station was selected for study based on the variability in cotton yields observed in previous production years.

The field had not been used for any small plot research and the variability present was attributed to natural variation and that introduced by normal field-scale production practices, consistent with a long, continuous cotton production history.

The field contains six different soil series (Routon, Henry, Grenada, Loring, Memphis, and Calloway) as well as a fragipan that varies in depth from 24 to more than 60 inches. A rectangular design was applied, resulting in 182 sampling grids, each measuring 20 ft. x 60 ft. At the grid intersections, soil samples were collected within a 10-foot radius to a depth of 6 inches, approximately one month after fertilization. Samples were composited and analyzed as follows: pH in water and salt solution; lime requirement using the Adams-Evans buffer test; Mehlich-1 phosphorus (P) and potassium (K); Mehlich-3 P, K, calcium

(Ca), copper (Cu), iron (Fe), magnesium (Mg), manganese (Mn), and zinc (Zn); cation exchange capacity (CEC); exchangeable bases; salt-extractable aluminum; and organic carbon content. Cotton yield data for the 1996 cropping season were obtained at harvest using on-the-go yield monitoring and were referenced to position using global positioning systems (GPS).

Soil Chemical Properties

Standard soil fertility assessment of the Milan cotton field, performed according to the UTAES guidelines (18 to 20 random subsamples representing no greater than 10 acres of similar soil), resulted in 'high' soil test ratings for both P and K. A 'high' rating suggests that the crop will yield at or near 100 percent of its potential without fertilization. That is, little or no response to fertilizer application would be expected. Site-specific sampling for soil K provided results that were similar to those obtained by the field-composited sampling. Of the 182 grids, 124 rated a 'high' soil test K and 56 rated a 'very high' soil test K. Only two rated a 'medium'. Increasing grid size reduced the sensitivity of soil test K estimates, but predicted crop response to fertilizer K was not affected.

Soil test P ratings for the cotton field were spatially variable and ranged from 'low' to 'very high'. A nine-fold increase in the grid size from 20 ft. x 60 ft. to 60 ft. x 180 ft. (0.25 acre) did not impact the estimate of soil P availability across the field. However, an additional increase in grid size from 60 ft. x 180 ft. to 120 ft. x 360 ft. (1-acre) had a pronounced impact on the perceived spatial variability of soil P. The 1 acre grid size also illustrates how grid point sampling can heavily weight extreme values, resulting in an incorrect estimate of the fertility level of the field. Indeed, site-specific P fertilization based on the 1-acre grid would result in over-fertilization.

The impact of expanding grid size on soil P availability estimates was also evident for other soil chemical properties. Mehlich-3 extractable Mg for the cotton field ranged from 76 to 542 lb/A and tended to be inversely correlated to soil P. Like soil P, the estimate of extractable Mg across the field was not greatly influenced when grid size was increased from 20 ft. x 60 ft. to 0.25 acre. However, increasing the grid size to 1 acre did significantly alter the extractable Mg estimate.

While site-specific soil testing can provide a detailed characterization of soil fertility across a field, the true test of the utility of precision farming, with respect to nutrient management, is the ability to correlate soil fertility to crop response (resulting in the more efficient application of nutrients).

The seed cotton yield for the production field ranged from 1,920 lb/A to 3,800 lb/A. Yield variability, however, was not related to soil fertility. A comparison of seed cotton yields, aver-

TABLE 1. Mean, standard deviation, minimum and maximum seed cotton yield as a function of soil test P.

Soil test P[1]	n[2]	Mean	Standard deviation	Minimum	Maximum
		Yield, lb/A			
L	31	2,818	343	2,078	3,417
M	37	2,940	384	2,336	3,821
H	98	2,904	407	2,203	3,812
VH	16	2,849	425	1,924	3,543

[1] Extractant for P is Mehlich-1 (HCl and H_2SO_4); L is less than 18 lb/A, M is 19 to 30 lb/A, H is 31 to 120 lb/A, and VH is greater than 120 lb/A extractable P.
[2] Number of 60 ft. x 20 ft. monitoring units within the 5-acre cotton field that were identified with the soil test level.

aged for each soil test P level, further illustrates that yields were not impacted by soil fertility status (**Table 1**). The mean seed cotton yield of 'low' P rated plots was only 31 lb/A less than the mean yield of 'very high' P rated plots. Further, mean yields of both the 'medium' and 'high' P rated plots were higher than the mean yield of the 'very high' P rated plots.

The lack of correlation between yields and measured soil fertility levels does not necessarily indicate that yields are not impacted by soil fertility. It is possible that low fertility areas are low currently because of past draw-down associated with good crop yields and nutrient removal. This could cause yields to become equalized among different fertility regions in the field over time. Also, fertility levels may not change independently of other soil parameters. To properly assess the potential for response to fertilizers in the field, treatments would need to be included in the study to measure possible yield increases, with collection of data over several years.

Summary

Precision farming research conducted at Milan identified the soil chemical variability that can exist in a production field and should help producers increase fertilizer use efficiency. However, important concerns still remain. Sampling grid size must be adequate to estimate the fertility level of a field while maintaining economic feasibility. Commercial operations generally rely on a 2.5-acre grid size for soil sampling. In the Milan field, a 1-acre grid size was too large to provide an accurate estimate of soil fertility. A site-specific assessment of soil fertility must provide information for cost effective nutrient management, relative to management based on field-average fertility levels. In 1996, cotton yield was not correlated with soil P, (or any of the other measured chemical properties) indicating that a whole-field sampling strategy was adequate for P fertilizer management. The results from the first year of study on this field indicate the importance of understanding the scale of variability before extensive sampling commitments are made. Several years of study will be necessary to determine the effectiveness and appropriate methodology for precision farming in Tennessee production agriculture. Fertilizer treatments should be included in precision agriculture research to more accurately evaluate the need for, and potential response to, nutrient additions in areas of fields with soil tests ranging from low to high. In large fields, as opposed to small plots, fertility levels may be positively or negatively correlated with other factors, such as: clay content, organic matter, soil drainage, compaction, acidity, water holding capacity, populations of plant parasites and diseases. Unless the variability and influence of these other factors are considered, as well as their relationships with soil fertility, there is a risk of making preliminary conclusions that could be in error. BC

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