ADOPTING PRECISION FARMING TECHNOLOGY FOR COTTON NUTRITION

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Abstract

This paper provides an overview of precision farming technologies that are entering the market place. It is probable that the technology will continue to develop and that its adoption in agriculture will grow. Precision farming products and services are being commercialized for cotton. Because soils are more fixed than are pest populations, precision-farming technology has been applied to sampling soils and managing plant nutrition before its application to other crop inputs, such as pest management. The factor that will determine the extent of the adoption of precision farming technology in cotton and agriculture generally, will be its net economic impact on growers.

Introduction

One definition of precision farming is the management of crop production resources and inputs by using production units smaller than the whole field. The purpose of managing on a small scale is to adjust inputs for the variability of topography and soils. Precision farming technology combines localized sampling, geodesic referencing, high-speed data management, and the capability to display geographic information. These technologies are capable of documenting variation in crop production systems at any scale. Precision farming technology does not minimize field variation; rather it organizes information that can be used to variably manage resources and inputs affecting crop growth.

In the early 1990's, the development of variable rate technology (VRT) for fertilizer application drove the commercialization of precision farming equipment and dealer services in Midwestern row crops. Currently, yield-monitoring technology is being developed and displayed at the distributor, dealer, and grower levels. Many farmers remain skeptical about the economics of precision-farming equipment and services (Lowenburg-DeBoer and Boehlje, 1996). In the Midwest, relatively few farmers use VRT and yield monitoring. In the South, even fewer farmers use VRT and yield monitoring, in part, because yield monitoring for cotton only became commercially available in 1997. In 1997, VRT application of fertilizer, based predominantly on grid soil sampling, was commercially available in many areas of the Cotton Belt. We anticipate that grid sampling for soil fertility evaluation and VRT use will increase in cotton.

Currently, cotton researchers are working to determine how farmers can utilize precision farming to improve cotton production efficiency and profitability. Some critical issues for precision farming are: 1) What spacing of sampling points best measures agronomically relevant variation? 2) Which operational scales are optimum for management? 3) Which scales of measurement and management optimize economic returns? And; 4) Does it make sense to purchase VRT services without being able to measure its benefits with yield monitoring?

Discussion

Cotton Nutrition

Cotton fiber and seed yields respond to amendments of plant nutrients, but not as directly as do yields of grain crops (Joham, 1986). Cotton is a perennial plant grown as an annual in warm temperate regions (Oosterhuis, 1990). Agronomic management is required to set fruit for a cotton crop, but insect management is required to protect and mature a crop. Grain crops often respond linearly to nitrogen over a broad range (Johnson et al., 1973; Pierre et al. 1977). Conversely, cotton's response to nitrogen is limited, with fruiting inhibited by high rates of nitrogen. A review of state recommendations suggests that cotton production requires about 50 lb of nitrogen per bale from all sources (Nichols, unpublished). Cotton also requires adequate supplies of phosphorus, potassium, and other nutrients, to achieve economically acceptable yield (Maples et al., 1992).

Soil Fertility Assessment

Historically, agronomic management has been based on representative sampling of whole fields, and the application of inputs based on averaged needs (Peck and Melsted, 1967). Intensive soil sampling within a field reveals substantial variability for most soil attributes (Wollenhaupt et al., 1997). Although variance in soil properties tends to increase with distance between sampling points, up to 50% of the total variation can frequently be found between points within one square meter (Beckett and Webster, 1971; Brown, 1993). Thus no scale of sampling intensity has been identified that best describes point-to-point variability of soil properties for the purpose of improving plant growth. Rather, growers and crop service providers base sampling protocol on issues such as topography, soil types, crop growth patterns, operational efficiency, and costs. Rectilinear grid sampling became a standard practice for VRT in the Mid-West and has been defended with empirical evidence that demonstrates its efficacy relative to other land sampling systems (Webster and Oliver, 1990).

Sampling on a 2.5-acre grid has become a de facto standard for quantifying soil variability for VRT application. We know of no theoretical justification for the 2.5-acre grid

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 1:627-629 (1998)
National Cotton Council, Memphis TN

system as compared to other grid sizes or other sampling patterns. The 2.5 acre grid is a practical solution that simplifies field sampling operations, gives two-dimensional displays on a scale that is acceptable by crop managers, and does not generate unacceptable sampling costs (Table 1.) Grid sampling may be a best approach when little is known about the variability of soils within a field (Webster and Oliver, 1990). However, growers typically have information about the physical character and biological history of their fields. Soils associated with major topographical features typically vary in predictable ways in drainage, soil water storage capacity, texture, organic matter, nutrient availability, and yield potential (Kharural et al., 1997). Growers clearly can observe topography, review soils maps, and may have extensive records on fertilization practices and crop yield histories. When information is known about the probable distribution of soil properties within fields, this method of directed sampling is advantageous in defining sampling locations (Pocknee, 1996).

Regional Research Planning

Cotton researchers have been documenting soil and yield variability for the past several years. During this time several hypotheses have been proposed to quantify and manage soil spatial variability. A general research protocol has been developed to document soil-spatial variability at different locations in the Cotton Belt and to evaluate soil-sampling strategies (Kvien et al., unpublished). Under this protocol, soil samples will be analyzed for nutrient availability, cation exchange capacity (CEC), soil texture, soil strength, and depth to a restrictive layer. For experimental purposes, intensive soil sampling will be done on a 100-ft x 100-ft grid and the results will be used to simulate a number of different, coarser-scale, sampling strategies. Statistical analysis of these data can be used to determine an optimum sampling intensity. In addition, previously- collected, whole-field information will be used to develop directed-sampling strategies. After harvest, soil sampling will be repeated to estimate nutrient removal and interpret yield differences. Yield will be measured by incremental catch and weigh systems or by experimental cotton yield monitoring systems. Uniform data collection methods were used in 1997 in Georgia, Missouri and Tennessee.

Cotton Yield Monitors

Yield is the end-of-the-year, agronomic report card and serves as a critique of agronomic management decisions. Yield mapping provides a visual, two-dimensional display of field productivity that can help identify problems or conditions that reduced or improved yield. Yield maps may also provoke questions concerning areas with high or low yields that are not explained by measured variables.

The development of yield mapping systems for cotton harvesters has lagged behind that of systems for grain combines. Cotton yield is difficult to measure because of the low density of the material and the use of pneumatic conveying on cotton harvesters. As early as 1988, research to measure cotton yield variability was reported by Pennington (1988), with subsequent work on developing a prototype yields monitor in 1989 (Thomasson, et al. 1998). This research had some encouraging results using a light-bar sensor to measure seed cotton in the air duct. Wilkerson, et al. (1994) built on this concept and reported on the measuring of seed-cotton flow in pneumatic conveyance. Their work included a light-source array that projected light across a cotton picker discharge chute. On the opposite side of the cute was a photo-detector array that measured the amount of light crossing the chute. Laboratory tests showed in a high correlation between the mass flow rate of cotton passing and the detector's output. Sensor performance during field tests was not as accurate due to variation in background lighting and trash particles in the flow stream.

In 1995, (Palmer, 1997) load cells were used on weighing baskets, in conjunction with global positioning system (GPS) equipment to measure cotton yield. A lightweight basket inside a conventional picker basket provided a satisfactory method of monitoring cotton yield variability for field-scale research in site-specific management. The weighing system was improved in 1996 by increasing the weighing capacity, ease of operation, and reduction of the basket-weight to cotton-capacity ratio.

In 1996, a system for yield monitoring was developed based on weighing the seed cotton as it was blown into a picker basket (Searcy, et al., 1996), which was mounted on load cells and isolated from the harvester frame. Yield values were determined from the changes in basket weight over a specific distance. The basket-weight data were noisy, due to the effects of mechanical vibrations and dynamic forces generated by the moving harvester. The estimates of yield did not compare well to manually harvested samples in the same areas. Later, additional signal processing and acceleration data were utilized to improve the basket-weight data.

In 1997, two commercial cotton yield monitors were introduced (Zycom and Micro-Trak) for cotton pickers. Both systems use optical sensors in the air ducts of the picker, GPS receivers, and data input/output devices. These systems have been involved in several evaluations during this past season. Both John Deere and J. I. Case have Research and Development efforts underway to develop a cotton yield monitoring system. Other researchers have attempted to estimate yield using remote sensing of defoliated cotton field. Remote sensing estimates are coarse measurement tools that can identify areas of low and high yields, but yields are difficult to quantify. Poor defoliation and weeds cause problems with yield estimation.

It would be dangerous to assume that seed cotton yields measured in a cotton picker would accurately indicate lint yield. Several factors such as seed cotton moisture, trash content, gin turnout and ginning efficiency affect the final lint yield per acre. Currently, there is considerable R&D work on cotton-yield sensors and we anticipate that commercial units will be further improved.

Variable Rate Nutrient Application

Variable rate nutrient application consists of applying fertilizers to the field based on site-specific data. With the results of intensive soil sampling and/or yield mapping, VRT can be used to match production inputs with yield goals. There are two different approaches to VRT, real-time sensing, and application by means of a prescription map. Real-time-measurement properties include soil-organic matter, nitrate, weed location, plant height, etc. Work at the University of Tennessee on the measurement of light reflectance is determining plant nitrogen status to apply nitrogen on the go. Other research in Texas and Georgia is studying the effect of varying the application rate of a plant-growth regulator as a function of sensed plant height. But the most common use of VRT equipment is the application of fertilizer and lime based on an application map. This equipment has the capability to determine field location, using GPS, and has a computer/controller that determines the desired application rate and adjusts the application equipment for that rate.

VRT accuracy must be compatible with machine width and performance characteristics. It is not practical to collect data at a scale that can not be managed by the equipment. However, if variable-rate field operations are not carried out with a high degree of accuracy, the placement of fertilizers and chemicals is no better than using broadcast methods (Schueller and Wang, 1994).

Comprehensive Management Tools

Use of precision farming information relies heavily on data management skills for data logging and organization, and on agronomic knowledge and experience for advantageous use of such data. A great deal of information can be collected, analyzed and displayed. To facilitate decision making, it is necessary to determine which data are closely associated with yields, and if and how the relevant variation can be managed in a cost-efficient manner. To benefit the grower, precision-farming technology must be combined with classical agronomic knowledge and economic analysis. Comprehensive enterprise management tools that use GPS field records, field attribute data, management inputs, and financial analysis are needed.

Economic Factors

Variable rate fertilizer application has been widely (ca. 30%) adopted by sugar beet growers in the Red River Valley of North Dakota (Cattanach et al., 1996). In sugar beet fields where residual nitrogen is variably distributed, the VRT is economically beneficial because sugar beet is a high value crop, and a premium is paid for higher sugar contents, which are highly correlated with plant nitrogen nutrition. In corn, soybeans and wheat, site specific management has proven to be profitable in only some cases (Lowenburg-DeBoer, 1997). Calculation of costs and benefits for precision agriculture must include several factors. Yields may be increased and fertilizer inputs may be decreased. Increased gross returns must cover the cost of equipment, employee training, dealer services, and the additional skilled labor needed to manage precision-farming field equipment and data-management systems.

Summary

The precision farming technologies are entering the market place. It is probable that the technology will continue to develop and that its adoption in agriculture will grow. Precision farming products and services are being commercialized for cotton. Precision-farming technology has been applied to sampling soils and managing plant nutrition before its application to other crop inputs, such as pest management. There are already agricultural businesses offering "geoprocessing" services. Such services collect, manage, and interpret site-specific data, and make recommendations from these data for crop production. Geoprocessors will need higher levels of training and will command higher salaries than the personnel now filling similar functions.

Economic analysis of precision agriculture has shown mixed results. The greatest likelihood of positive returns have been in high-value crops when yield or quality was strongly associated with a single factor, and that factor, was variably distributed and manageable. Economic implementation of precision farming technology will require an integrated model that includes analysis and interpretation of the field data, means to implement the recommended practices, and tools to evaluate costs and returns.

Acknowledgment

The authors acknowledge the support and dedication of the many Beltwide cotton researchers and Cotton Incorporated staff who have contributed to the improvement of cotton production systems.

Mention of a manufacturer or product does not indicate its approval by Cotton Incorporated at the exclusion of others.

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Table 1. Grid Sampling Comparison.

Sampling Unit Size (acre)	Point-To-Point Distance (ft)	Points/ 40 acres	Cost/Acre * ($)
15.6	824	2.6	0.65
6.2	522	6.4	1.60
2.5**	330	16.0	4.00
1.0	209	40.0	10.00
0.25	104	100.0	40.00
0.10	6	400.0	100.00

* Estimated at constant cost per sampling point, with reference of $4 for one sample/2.5 aces

** Mid-West commercial VRT standard, per acre cost is estimated