2004 BELTWIDE COTTON CONFERENCES, SAN ANTONIO, TX – JANUARY 5-9

DEMONSTRATING THE BENEFITS OF VARIABLE RATE NITROGEN APPLICATIONS FOR CALIFORNIA COTTON PRODUCTION

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Introduction

The use of yield monitors, global positioning systems, remote sensing, and other attributes of site-specific crop management is increasing in California. California farmers who have adopted yield monitoring and mapping technology have frequently observed a high level of yield variability in their fields. In some cases growers have been able to interpret these yield maps based on their knowledge of the field and use this interpretation to improve their management and enhance profitability. However, the level of knowledge of this technology has not yet reached the state where growers can confidently adopt on a wide scale true site-specific management practices, that is, practices in which management is adjusted "on the go" to match the specific needs of each location in the field.

One of the most promising site-specific management practices is variable rate input application. In particular, variable rate application of fertilizers, especially fertilizer nitrogen, has been extensively studied in Midwestern cropping systems. Scientific investigations of the profitability of variable rate nitrogen application in the Midwest have produced equivocal results, with some investigations indicating a profit and others not. Much of the work in the upper Midwest has been motivated by regulatory concerns associated with potential contamination of ground and surface waters. This is also becoming an issue in California. Variable rate nitrogen application offers the potential for increasing profitability and reducing environmental effects of crop production if the increased costs associated with the practice can be offset by reduced input costs and/or reduced regulatory pressure.

In order to achieve a workable variable-rate fertilizer management program it is necessary to be able to estimate with sufficient accuracy the crop's site-specific nitrogen demand prior to the time of fertilizer application. A number of researchers have found that under growing conditions of the semi-arid and arid West, Cotton removes approximately 50 to 60 lbs. N per bale of lint. It requires an additional 100 to 150 lbs./acre of N to support vegetative growth. Most of this latter N is returned to the soil when cotton stubble is disked in. Travis et al. studied over a five-year period the relationship between soil test nitrate levels and crop response to applied soil N. They found that at the field scale there is a general relation in which low soil test nitrate levels correspond to a higher yield response to applied N and high soil test nitrate levels correspond to a lower yield response to applied N. They also found that there was considerable variability in this relationship, which they attributed in part to within-field variability in soil and nitrogen conditions. We hypothesize that the precision of the relationship between soil test nitrate level and plant N response can be improved by a stratified sampling scheme taking into account within-field variation in soil conditions. Based on this working hypothesis, we developed a practical site-specific variable N rate application program for California cotton production.

Objectives

The overall objective is to determine whether variable rate nitrogen application is economically justified in California cotton production and if so, to determine a practical method for implementing it. Specific objectives are

1. Develop a practical method for creating variable rate fertilizer nitrogen application maps based on existing yield maps, remotely sensed NDVI images, and /or soil bulk electrical conductivity maps and soil nitrate N levels obtained through directed pre-season sampling.
2. Conduct replicated experiments in large (typically quarter section) commercial fields in which the treatments are variable rate fertilizer application, fixed rate fertilizer application, and control.
3. Conduct a partial budget economic analysis based on established methods to determine the economic viability of variable rate fertilizer application for California cotton production.

Project Description

The experiments carried out in this research project focus on using high spatial precision bulk data (yield maps, remotely sensed images, and soil bulk electrical conductivity (EC_a) values obtained from EM-38 or Veris instruments) together with soil nitrate levels in the top two feet, obtained from soil cores taken through a directed sampling plan, to determine variable application rate in the first N application at layby. Each experiment is carried out as a randomized complete block design with four levels: variable N rate, low fixed N rate control, nominal fixed N rate, and high fixed N rate. In 2002 the experiments were carried out in three fields whose locations are shown in Fig. 1. Due to technical problems only one field was tested in 2003, and we anticipate that two or three fields will be tested in 2004. The variable rate treatment is applied at a rate determined by an application rate map constructed according to soil productivity and estimated residual available N. We begin with relatively inexpensive, high spatial resolution data sets for the field: a yield map and bulk EC (i.e., EC_a) map. Based on the yield map the field is subdivided into three regions: high, medium, and low yield. Three soil sample locations are selected from each of these regions. Figure 2 shows the yield map and soil sample locations for the Sheely 6-4 field.

Based on soil samples taken at these locations an estimated residual N map was developed. This map is shown in Figure 3. Using this map in combination with the soil EC map a set of fertilization zones was developed. These zones are shown in Figure 4. At the Sheely site there were only two zones, while at each of the other two sites there were three zones.

Figure 5 shows the mean yields of each treatment. There was no significant yield difference between the VRT treatment and the intermediate or high fixed rate treatments. This indicates that there is no loss in profitability by withholding nitrogen from areas in the field with low potential yield.

Although in principle the VRT approach could result in increased yields through more fertilizer being applied to high yield potential areas, in each of our test sites the variation in rate was always due to reducing N application in low yield potential areas. Therefore an increase in profitability must come from a savings in fertilizer costs sufficient to offset the costs associated with the VRT program. The savings in fertilizer expenditures were substantial. Table 1 shows the percent reduction in midseason nitrogen fertilizer expenditures that is obtained through the VRT program at each of the test sites. There is a substantial reduction at each site.

The question of increased costs associated with the VRT program is a subtle one and depends on how these costs are spread over other operations. This in turn depends on the size of the farm, on the other crops grown on the farm and whether they can also be fertilized according to a VRT program, whether a VRT program can be developed for other nutrients besides nitrogen, as well as for other inputs such as soil amendments and pesticides, and for how many years the grower can use the VRT equipment before it becomes obsolete. In order to obtain a conservative estimate of the cost we have carried out a partial budget analysis that is summarized in Table 2.

As indicated in the table, when all of the costs are assigned to a single quarter section field (the most conservative possible assumption, the VRT program does not pay for itself. The profitability of the program therefore depends on how many fields and how many operations the grower can implement the program on per unit of equipment. For simplicity, if we assume that the same number of fields can be managed with both one fertilizer rig and one cotton picker, then the decline in cost differential as a function of size is shown in Fig. 6. In reality, the situation is more complex since the number of fields per fertilizer rig is different from the number per picker. The primary contribution to equipment expense is the cost of the yield monitor. At 480 acres the VRT program is approximately equal to the fixed rate program. Therefore if the farmer does one of the following: (1) manage more cotton fields than three quarter sections for each piece of equipment, (2) manage other cotton operations besides nitrogen fertilization using the VRT controller, (3) manage and harvest other crops besides cotton using the VRT equipment, or (4) use the equipment for more than five years, then variable rate fertilization should be profitable in the San Joaquin Valley. As the cost of yield monitors and controllers declines, which it is likely to do, the VRT program will become more profitable.

Acknowledgements

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Julie A. Young, Informatics Center, College of A&ES, University of California

Karen M. Klonsky, Dept. of Agricultural and Resource Economics, University of California

Sylvain Grellet, Department of Agronomy and Range Science, University of California

Table 1. Percent reduction in mid-season nitrogen application costs, in comparison with the fixed late treatment used on the rest of the field, at each of the sites.

Sheely	Woolf	McKean
-32.73%	-44.69%	-23.29%

Table 2. Partial budget analysis of VRT program on each of the three farms, assuming that the equipment is depreciated over five years.

OPERATION	Sheely Fixed	Sheely Variable	Woolf Fixed	Woolf Variable	Mc Kean Fixed	Mc Kean Variable
			$/acre			
Soil Samples	2.64	3.18	2.64	3.18	2.64	3.18
Recommendation Map		2.00		2.00		2.00
Fertilize	29.48	21.40	29.13	18.09	49.73	39.27
TOTAL FERTILIZER COST/ACRE	32.12	26.58	31.77	23.27	52.37	44.45
Operating Interest	1.16	0.98	1.15	0.85	1.89	1.61
TOTAL OPERATING COST/ACRE	33.29	27.56	32.92	24.12	54.26	46.06
CASH OVERHEAD:						
Property Taxes	3.68	4.19	3.68	4.19	3.68	4.19
Property Insurance	2.48	2.83	2.48	2.83	2.48	2.83
Investment Repairs (Yield Monitor)		0.81	0.00	0.81	0.00	0.81
TOTAL CASH OVERHEAD	6.16	7.84	6.16	7.84	6.16	7.84
TOTAL CASH COSTS/ACRE	39.45	35.40	39.08	31.96	60.42	53.90
NON-CASH OVERHEAD:						
Yield Monitor	0.00	5.59	0.00	5.59	0.00	5.59
Equipment	66.66	81.60	66.66	81.60	66.66	81.60
TOTAL NON-CASH COSTS/ACRE	66.66	87.18	66.66	87.18	66.66	87.18
TOTAL COSTS/ACRE	106.11	122.58	105.74	119.14	127.08	141.08

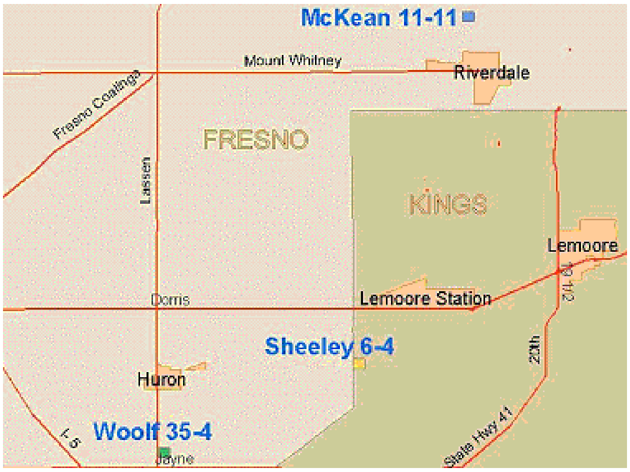

Figure 1. Locations where experiments were carried out in 2002.

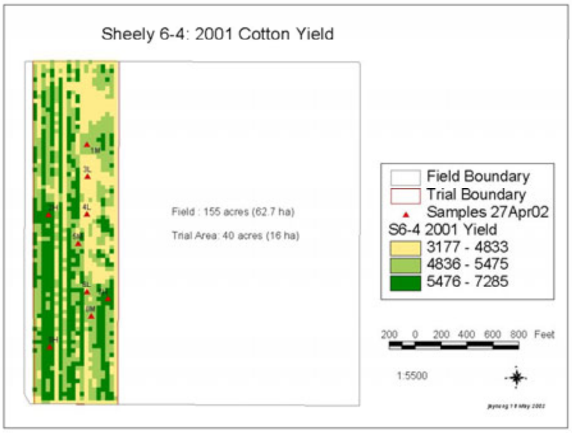

Figure 2. Yield map showing 3 yield classes and soil sample locations stratified by yield class.

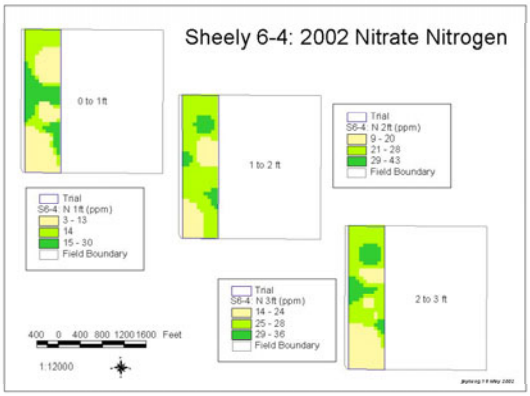

Figure 3. Estimated residual nitrate N based on interpolated soil samples.

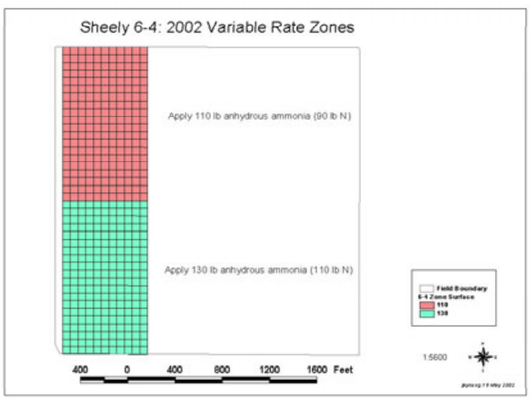

Figure 4. Variable N rate zones based on estimated residual N and soil bulk EC.

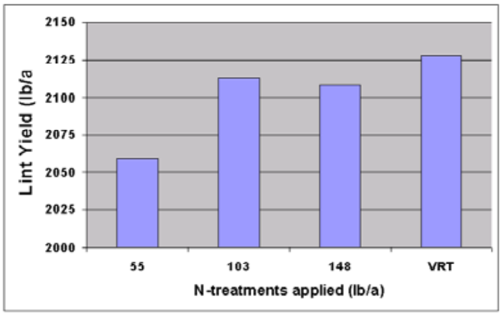

Figure 5. Mean plot yield for each of the treatments at the Sheely 6-4 site in 2002.

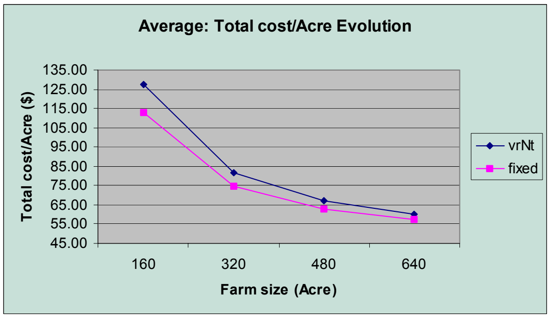

Figure 6. Costs of VRT and fixed rate program as a function of farm size per unit of equipment (fertilization plus yield monitoring).