Site-Specific Variable Rate Fertilizer Application in Rice and Sugar Beets

FREP Contract # 00-0505

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Introduction

Large fields are rarely uniform, yet they are often farmed as if they were. New management technologies are being developed, however, which allow variable application rates of fertilizers, soil amendments, seed, and pesticides. These make use of satellite based global positioning system technology (GPS) to locate places within a field that may vary in some important soil property like nitrogen content, water holding capacity, or salinity. Such practices are generally termed site-specific management or precision agriculture.

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. The potential for variable rate fertilizer application to increase profit and resource use efficiency has not been investigated scientifically for California's diverse irrigated cropping rotations. Many laser leveled, surface irrigated fields in California display a high level of spatial variability in yield. Therefore the potential for improved economic and resource use efficiency of fertilizer exists, either by adding fertilizer to areas in which yield is limited by mineral nutrients or by reducing fertilizer rates in areas where yield potential is sufficiently reduced that high rates are unwarranted.

To maximize its economic impact, an initial variable-rate nitrogen management research program should focus on systems for which a substantial economic advantage accrues to the use of site-specific management. Maximum economic payoff is obtained in those crops for which there is a relatively large economic penalty for both under- and over-fertilization and a relatively narrow range of optimal fertilizer rates. Two crops that meet these criteria are specialty rice (Koshihikari and Akitakomashi) and sugar beets. While these crops are not major contributors to California economically, they are ideal for an intial test of site-specific fertilization. For both of them the primary economic penalty associated with over-fertilization is in quality reduction. In the case of specialty rice, increases in nitrogen levels have been identified with increased protein content, which in turn has been associated with poor flavor. In the case of sugar beets high levels of soil nitrate are associated with reduced sugar concentration. In both crops the factor causing a reduction in quality is readily quantifiable and therefore subject to rigorous analysis. The questions we are addressing include the following: Will the money saved by applying fertilizer at variable rates cost less than the assessment and equipment needed for such work? Will crop yield be improved? Or at a minimum, will these technologies allow farmers to comply better with increasingly restrictive environmental regulations? To further broaden the study we have included standard rice varieties as well.

Soil salinity is an important management factor for many sugarbeet growers in the Imperial and San Joaquin Valleys. Salinity can inhibit seedling emergence and limit crop growth. Salinity or texture assessments can be carried out quickly and relatively cheaply and used prior to planting to guide management for the upcoming growing season. The salt content of soils also is correlated with soil physical characteristics like water holding capacity. There may also be other useful correlations with soil properties that are much more difficult to map accurately, like nitrate content. One of the most perplexing problems for sugar beet production in the San Joaquin Valley is low sugar content. Residual soil nitrate at depth in the profile may be a factor contributing to low sugar content. It is very difficult to assess a field's variation in nitrate even when only one and one-half to three feet of the soil surface is sampled. The complexity of the problem is increased greatly when nitrate in the second three feet is included. Sugar beets are deep-rooted and take up some water and nutrients from the four to six foot depth (and sometimes deeper) in many soils, especially near the end of the growing season. Like salts, nitrates are soluble in water and move downward in the profile as soils are leached by irrigation and rainfall. Unlike salts, nitrates have an active role in plant growth and soil biology and so are subject to plant uptake and transformation by soil organisms. Nevertheless, nitrate and salt may be sufficiently well-correlated to allow mapping for salinity, which is relatively simple and reliable, to be used as an indicator of potential nitrate hot spots deeper in the profile. These areas could be tested to six feet, and if confirmed, fertilizer application rates may be adjusted accordingly in those portions of the field.

Objectives

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

1. For rice, determine whether the spatial distribution of crop nitrogen demand can be forecast with sufficient precision on a site-specific basis using aerial photographs, yield monitor data, or other data readily obtainable by the farmer.

2. If the spatial distribution of crop nitrogen demand can be adequately forecast for rice, determine whether the improvement in quality and/or yield is sufficient to offset the increased cost of the variable rate technology.

3. For sugar beets, determine whether crop nitrogen demand can be forecast with sufficient precision using electrical conductivity, soil texture, remotely sensed images from the previous crop, or other available data.

4. If the spatial distribution of crop nitrogen demand can be adequately forecast, determine whether the improvement in quality and/or yield is sufficient to offset the increased cost of the variable rate technology.

5. If economically justified, develop a set of practices for implementing variable rate nitrogen application on these crops. Produce a bulletin or technical manual on variable rate nitrogen application. We will target this manual to fertilizer companies, precision ag companies, and growers.

Results and Conclusions

Sugarbeets:

Imperial Valley site:

1. Previous yield maps and a new electrical conductivity survey were carried out and used to to develop a treatment plan for the Imperial Valley site.
2. Gypsum at the rate of two tons per acre was applied to the tops of beds in 20 plots (four 30" rows, 60 feet long) chosen using the ESAP v2.01 software created by Scott Lesch of the U.S. Salinity Lab, in Riverside. These twenty sites represent the range in salinity conditions found in the field.
3. Supplemental nitrogen fertilizer (at the rate of 100 lb N per acre, applied in addition tothe baseline rate of 150 lb N per acre) was applied to half of the twenty sites, which were divided to reflect approximate balance between each group of ten plots with respect to salinity conditions.
4. Prior to planting and irrigation, soil cores were collected to three feet at each of the twenty sites and analyzed for salinity and clay content for calibration with the conductivity maps made earlier by Corwin and Lesch.. An additional set of soil samples to six feet was collected at harvest in late May and were analyzed for salinity, clay content and nitrate.
5. Seedling emergence was counted at each of the twenty sites two weeks after initial irrigation. Soil samples were taken at each site on the same day at the two to three inch depth and are being analyzed for salinity and sodium content.
6. Petiole samples were collected at most of the plot sites during the spring and at harvest to follow changes in plant nitrate content and see if those changes are related to soil conditions.
7. At harvest, a yield monitor was used to map sugarbeet yields and those yield maps will be combined with the previous year's maps for sugarbeet and wheat and soil electrical conductivity to evaluate the effects of soil variability, including residual and applied N on on crop performance.
8. Hand harvests were be taken at the twenty plot sites and analyzed for yield, quality, and root characteristics, root NO3 content.
9. All data are being combined and analyzed.

El Nido site:

1. In the spring of 2000, an EM 38 survey was carried out on a 60 acre site in El Nido, California by Dennis Corwin of the U.S. Salinity Lab, in Riverside.
2. Following the survey, soil samples were collected at 16 sub sample locations chosen using the ESAP v2.01 software. Samples were analyzed for salinity, texture and nitrate.
3. Sugarbeets were planted at the El Nido site in May, 2001. They were harvested in mid-May 2002.
4. Stand counts were made at emergence in June 2001 and will be correlated with soil properties.
5. Supplemental fertilizer applications at rates of 50 or 100 lbs N per acre were side dressed to young beets before canopy closure. Two 50 rows were fertilized at each of 16 sub sample locations. Sites were divided into two approximately equal groups, half receiving the larger rate, and half the smaller. Results are being compared to neighboring rows using hand harvests at each location. Background variation in soil residual N and the variable amounts surface applied will be used to assess crop fertilizer response.

6. A yield map of the field was made at harvest. Data are being analyzed.

Summary:

Neither fertilizer N nor gypsum affected sugarbeet root yields significantly at the IV and EN sites. Petiole NO_3-N levels were increased, and sugar contents decreased with increasing fertilizer N. or amendments were applied (gypsum and N in the IV, and N only in El Nido). Soil physical and chemical conditions limiting crop growth and yield could not be significantly modified to overcome salinity and drainage limitations at the IV site, nor soil structural and hardpan problems at the EN site. A complete report is in preparation.

Rice

Nitrogen trials were established in two commercial rice fields in the Sacramento Valley. One field was Akitakomashi and one M202. This gives us the opportunity to observe how the interaction of nitrogen with rice quality differs between Japanese and American varieties. All fertilizer applications are carried out by the growers as a part of their regular operation. The layout of the experiments has been designed to take into account the realities of commercial rice production. Therefore, the trials are not laid out in a randomized, replicated manner. Rather, they consist of three large individual blocks (un-replicated) in which nitrogen fertilizer is applied at 50%, 100%, and 150% of the normal rate the grower uses in that field. Blocks are measured using a yield monitor at harvest and data is analyzed using multivariate regression techniques. Grain samples will be hand harvested on a regular grid for grain nitrogen analysis. Other primary data will include yield maps of the harvest. Remotely sensed aerial images are being collected, and these will be used to infer a measure of vegetative N demand.

Two different field trails were carried out during the 2001-growing season and they were repeated during this current season.

Trial 1: Schohr Ranch, Gridley CA: 3 different pre-plant N rates were tested, 57, 100, and 167 lb/a N (Figure 1). Cultivar: M 202.

Trial 2: Gorril Ranch, Richvale CA: A combination of 4 different pre-plant and 3 different top-dressing treatments was tested. Pre-plant: 32, 46, 61 and 75 lb/a N. Top-Dress: 0, 20 and 30 lb/a N.(Figure 2). Cultivar: Specialty rice Akita.

Both fields were harvested with combines using yield monitors. Besides the yield and moisture data from the yield monitor, samples were taken at each sub-plot for yield components analysis using a DGPS. At early, mid and late growing season stages multi-spectral aerial images were taken. At the Schohr trial soil and tissues samples were taken at the same locations where the yield components samples were taken.

Results

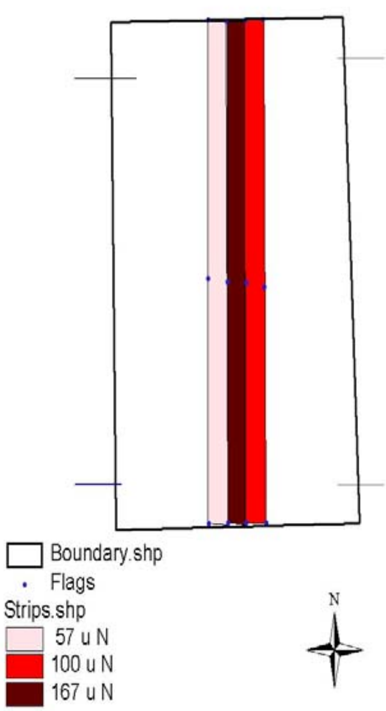
Trial 1: Significant yield differences were found at this site (Figure 3). The 57 lb N that was the lowest application rate presented an intermediate yield. The farmer pointed out that in this treatment the harvest operation was much quicker than in the other two due to the lower amount of plant material that entered the combine. In order to quantify this, 310 meter strips of each treatment were analyzed from the yield map. The combine registered a yield data each second. Table 1 shows the combine velocity at each treatment.

N level	**57**	**100**	**167**
# of yield data points	347	379	433
Distance	310	310	310
Velocity (m/s)	310/347= 0.89	0.82	0.71

The higher velocity registered at the lowest N application can have potential economical advantages when it is extrapolated to the whole ranch area. For a closer look at this issue an economic analysis of the impact of the different pre-plant treatment will be carried out.

Trial 2: Significant yield differences were found in the pre-plant treatments (Figure 4). An interaction between pre-plant and top-dress treatments were found. While at the 32 and 46 lb N they were an increase of yield with the top-dress applications up to 30 lb N; at the 61 lb N treatment the maximum yield was achieved at the 20 lb N top-dress application.

These data suggest that this cultivar requires a total of approximately 80 lb N to achieve its yield potential.



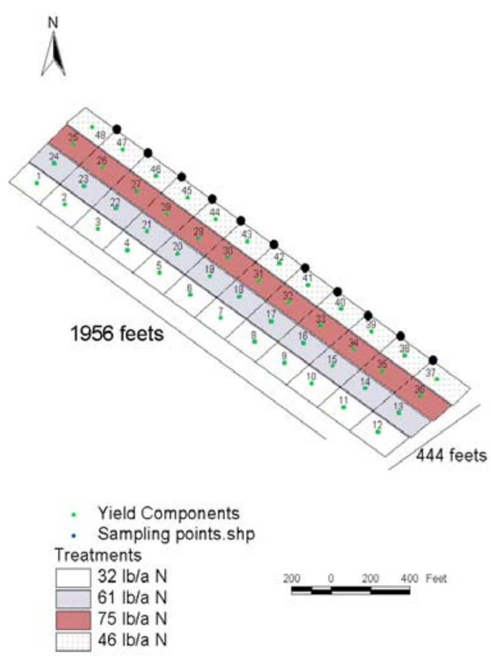
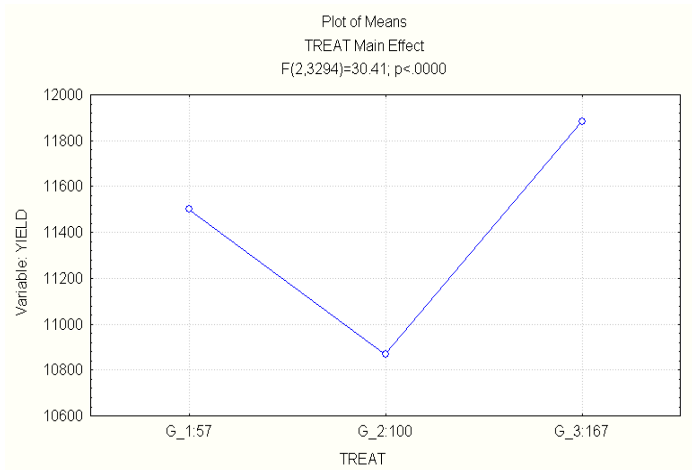


Figure 1: Schohr Ranch

Figure 2: Gorril Ranch



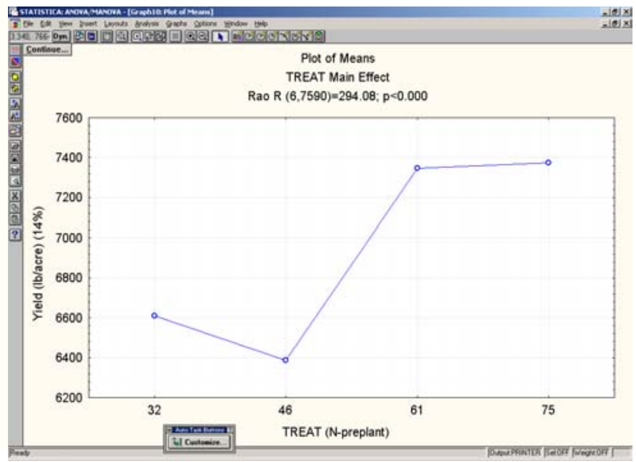


Figure 3: Schohr Ranch, Yield at the different pre-plant N levels.

Figure 4: Gorril Ranch, Yield at the different pre-plant N levels.