Precision-Water, -Nitrogen and -Seed Management for Enhancing Efficiency, Productivity, and Profitability of Irrigated Cropping Systems.

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Introduction

Farmers have a growing interest for precision management techniques that have the potential to enable them to produce more with less. The market is offering numerous solutions to help farmers take advantages of data from different sources and technologies that are now accessible to them. However, with this growing interest come a growing number of questions concerning the potential of new approaches such as precision irrigation, site-specific N management, and/or variable-rate seeding.

It has been broadly documented that spatial variability in soil properties and yield exists in most fields (Mulla and McBratney 2001; Vieira and Gonzalez 2003; Longchamps et al. 2015). Several methods have been designed to characterize spatial variability such as management zones delineation (Khosla et al. 2002), crop canopy sensing (Inman et al. 2007) or proximal soil sensing (Corwin et al. 2005). The agricultural industry has started to use some of these techniques in order to increase the precision with which inputs are managed and thus increase efficiency of the farming system (Whipker and Erickson 2013). However, precision management is a fairly young field of research and while important discoveries have been done, several aspects are yet to be studied. One important aspect of precision agriculture that has not received a lot of attention by the scientific community is the interactions that take place when multiple inputs are modulated. For instance, it is logical to think that an increase in the seed rate should be accompanied by an increase in N fertilizer and irrigation. Indeed, a higher competition for water and N under dense vegetation cover may have a negative impact on yield (Imran et al. 2015). It is thus believed that a holistic approach should enable the determination of an optimal combination of inputs at every location of the field to maximize profit (Figure 1).

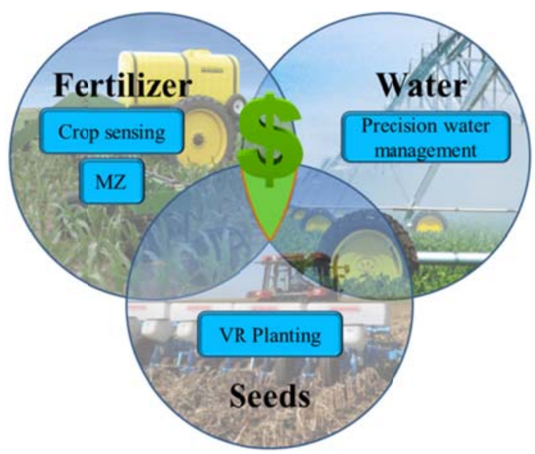

Figure 1. Holistic crop management approach optimizing seed, irrigation and fertilizer rates.

The overall goal of this project was to research and demonstrate the most productive, efficient, profitable and sustainable variable rate-water, -nutrient and –seed management strategies for irrigated cropping systems. The specific objective addressed in this 2015 report was to evaluate variable rate seeding in conjunction with variably managed water and nitrogen fluid fertilizer.

Materials and Methods

Study site and treatments

This study was conducted in Colorado during the 2015 crop growing season (from May 2015 to October 2015). The climate of north-eastern Colorado is considered semi-arid as it receives less precipitation than potential evapotranspiration. The 2015 crop growing season was delayed compared to other years due to unusual wet Spring season. Planting occurred on May 27th when the planting date is typically around May 1st. Likewise, the first frost occurred on Oct. 24th in 2015 when the typical frost date is around Oct. 5th in past years. The 22 acre field where the study was conducted is located at the Colorado State University's Agricultural Research Development and Education Center, Fort Collins, Colorado (40° 40' N, 104° 58' W). The soil at this site is classified as a fine-loamy, mixed, superactive, mesic, Aridic Haplustalf (Soil Survey Staff, 1980). Based on soil samples, soil texture was classified as a sandy clay loam. The slope is less than 2% in a single plane gradient. This site has a history of continuous maize production with conventional tillage. Corn hybrid Dekalb 4620 was planted at a seed rate of 20,000, 27,000, 34,000, 41,000 and 48,000 seeds/Acre (depending on seed rate treatment strips). Seeds were planted using a precision planter in long experimental strips (see labeled strips in Figure 2). Fluid N fertilizer (UAN 32%) was applied at the crop growth stage of V5 (5-leaf) and at five N rates: 0, 50, 100, 150, and 200 lbs N/Acre in conjunction with seed rates (Figure 2).

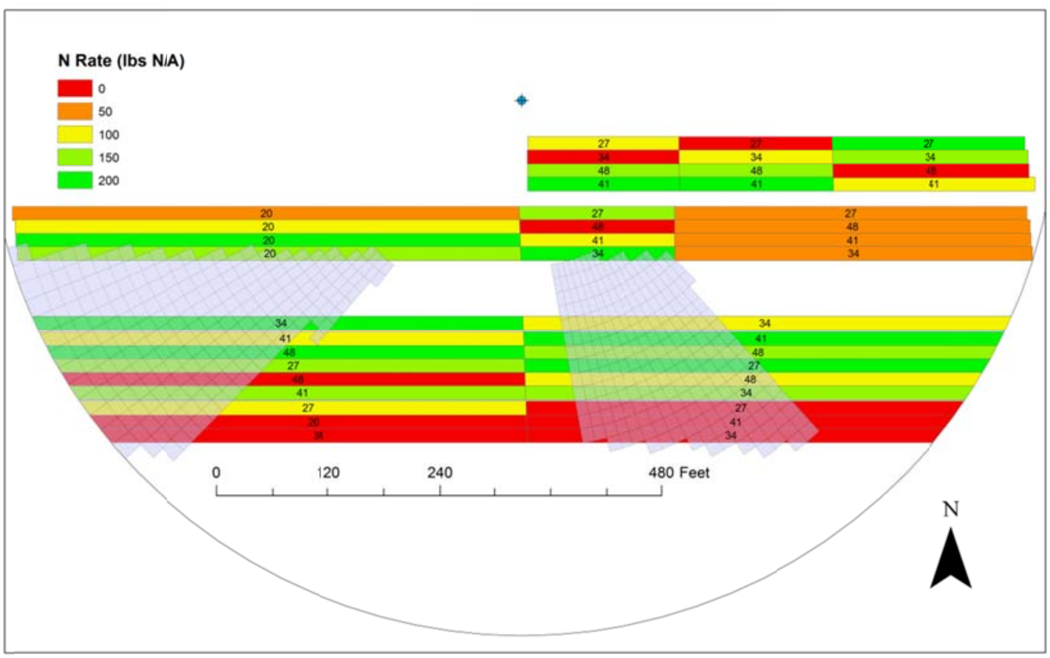

Figure 2. Map of N rate, seed rate, and irrigation treatments for the 2015 crop growing season. Colors indicate the N rate, labels (black numbers) indicate the seed rate in 1,000 seeds/Acre and limited irrigation area (80% ET) is shown as a clear grayed area. The rest of the field (i.e. none grayed area) received full irrigation (i.e. 100% ET).

Combinations of N and seed rates were randomly assigned. Irrigation was applied with a Valley precision sprinkler irrigation system to compensate for crop evapotranspiration (ET) using the web-based irrigation scheduler eRams (www.eRams.com). Two irrigation rates were applied throughout the crop growing season to attain irrigation rates that would correspond to 100% of ET and 80% of ET. The irrigation rate corresponding to 80% of ET was placed as shown in Figure 2 (see clear grayed area) and the remainder of the study area received irrigation corresponding to 100% of ET. Corn grain was harvested with a 6-row combine harvester equipped with a GPS enabled yield monitor. Grain yield was corrected to a 15.5 % moisture content. Geographic information software was used to join yield data points from the yield map to the treatments map. A distance of 2 m from treatment transition areas and field borders was used as a buffer to exclude data points considered as non-representative of imposed treatments.

Data analysis

The effect of seed rate on corn grain yield was tested in conjunction with irrigation for an N rate of 150 lbs N/Acre. We have tested the difference in corn grain yield between limited (80% ET) and full (100% ET) irrigation for five seed rates. A Student's *t* test with a significance level of 0.05 was used to verify the difference in yield between limited and full irrigation for each seed rate. Subsequently, the effect of seed rate on corn grain yield was tested in conjunction with N fluid fertilizer application for an irrigation rate of 100 % ET. We have tested the difference in yield among five N rates (i.e. 0, 50, 100, 150, 200 lbs N/Acre) for five seed rates. A Tukey's test with a significance level of 0.05 was used to verify the difference in corn grain yield among the contrasts of N rates. Statistical analysis was done using the software R (R Core Team 2015).

Results and Discussion

Water and seed rate

Comparing corn grain yield based on irrigation and seed rates showed that there is an interaction between these two parameters (Figure 3). At low seed rates (i.e. 20,000 or 27,000 seeds/Acre), the irrigation rate has no effect on yield. However, at higher seed rates (i.e. 34,000 seeds/Acre and above), the yield was higher under full (100% of ET) irrigation. This indicates that irrigation and seed rates are influencing each other. From our results, a higher seed rate should be accompanied by a higher irrigation rate. Conversely, when practicing limited irrigation, seed rate should be reduced accordingly in order to make the best use of both water and seeds. For example, at 27,000 seeds/Acre, full irrigation did not improve yield as compared to limited irrigations, which indicates that water was over-applied. Conversely, at 34,000 seeds/Acre the seeds did not reach full yield potential under limited irrigation, which indicates that water was under-applied. El-Hendawy et al. (2008) observed that for irrigation corresponding to 100% ET, the yield increased from 19,400 seeds/A to 28,700 seeds/Acre, but decreased at higher seed rates. Our results confirmed our hypothesis that when the seed rate is modulated, irrigation should be taken into consideration as well.

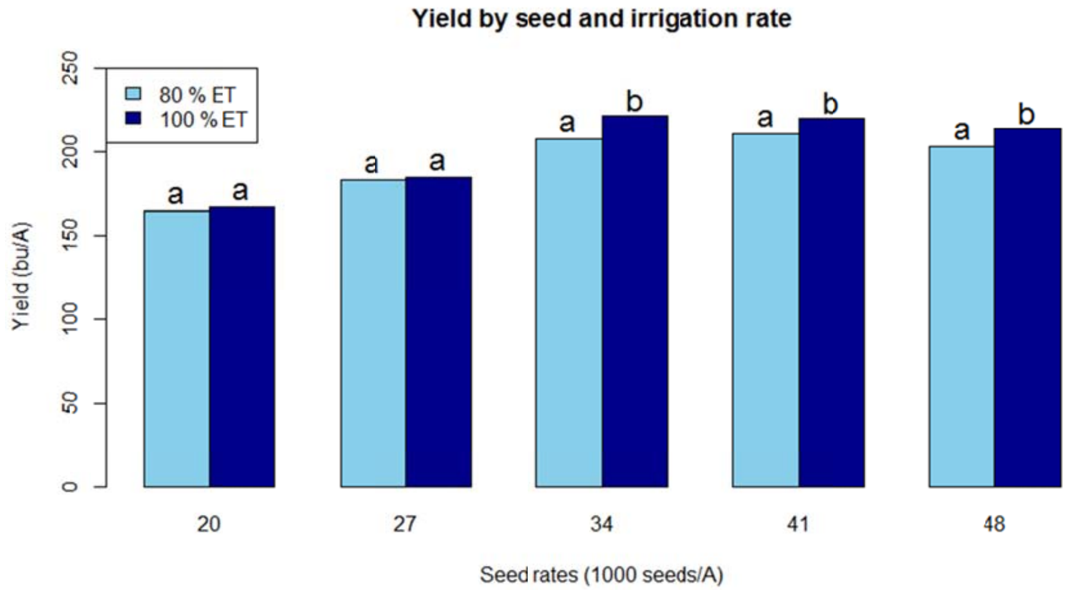

Figure 3. Differences in grain yield due to irrigation for five seeding rates. Different letters indicate significant statistical difference (alpha=0.05) within each seed rate.

Nitrogen and seed rate

We observed significant interactions between the seed rate and the N rate. In Figure 4, the lowest N rate giving a yield not significantly different from the maximum yield should be considered as the optimal N rate. For example, the optimal N rate for a seed rate of 20,000 seeds/Acre was 100 lbs N/Acre based on Figure 4. With this consideration, the optimal N rate was 100, 100, 150, 150 and 100 lbs N/Acre for the seed rates 20,000, 27,000, 34,000, 41,000, and 48,000 seeds/Acre respectively. These observations tend to confirm the hypothesis that a higher seed rates requires higher N supply. The only exception is the seed rate 48,000 seeds/Acre for which the optimal N rate was lower. This anomaly may potentially be related to local soil properties favoring the yield in the 100 lbs N/Acre x 48,000 seeds/Acre treatment area. It is also possible that the yield potential of our field is around 225 bushels/Acre and that other yield limiting site properties have masked the beneficial effect of maximum seed rate (i.e. 48,000 seeds/Acre) combined with maximum N rate (i.e. 200 lbs N/Acre), which emphasizes the importance of site characterization for variable rate seed and N management. In a study conducted in Pakistan, Arif et al. 2010 studied the combined effect of N and seed rates and observed the highest corn grain yield with the highest N and seed rates, but their highest yield was 60 bushels/Acre, which is way below the maize plant grain yield potential. Nevertheless, our results show that there is a trend suggesting that a higher seed rate should be accompanied by a higher N rate to compensate for higher competition for N under dense crop cover.

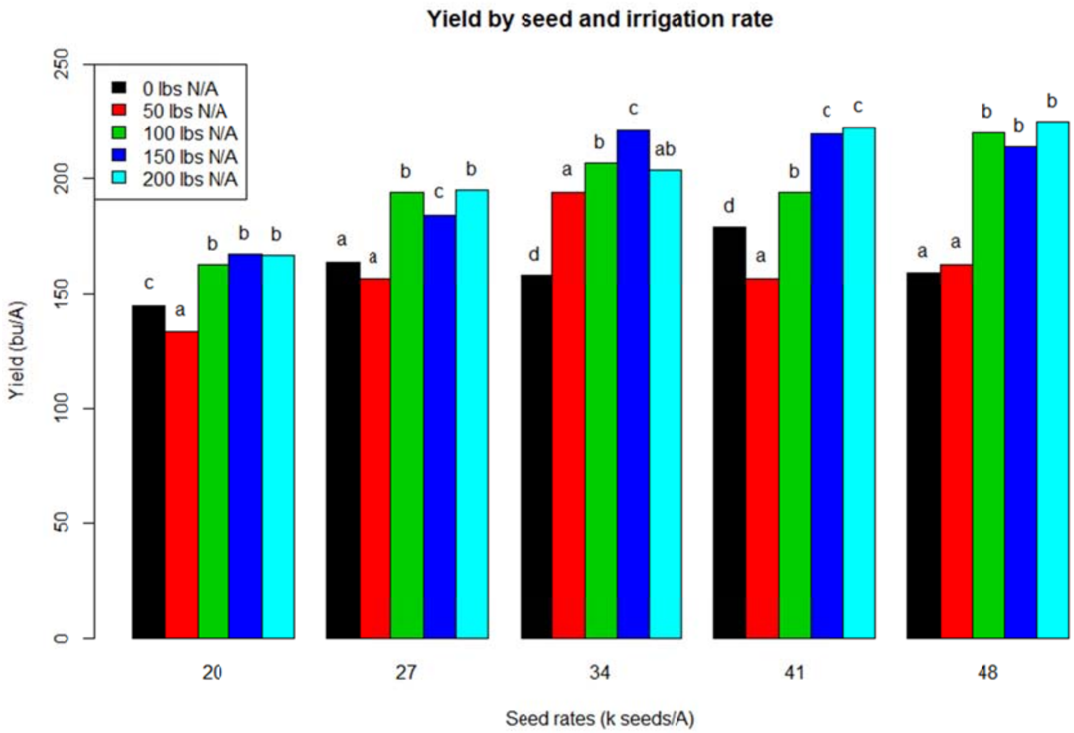

Figure 4. Differences in yield for different N and seed rates. Different letters indicate significantly different yield within each seed rate. Alpha=0.05.

General Conclusion of the overall three year Project

This experiment was conducted over three years from 2013 to 2015. The objectives were to (i) quantify spatial and temporal variability in soil water balance across the 22 acre precision pivot equipped field, (ii) develop early season (corn growth stage V4-V6) in-season precision nitrogen management system for irrigated corn, and (iii) evaluate variable rate seeding in conjunction with variably managed water and nutrient crop field. Studying the soil water content across two entire fields, we were able to demonstrate that there is significant amount of spatial and temporal variability, which may justify spatial and temporal management of irrigation water. We found that there is more spatial variability near the soil surface than at deeper depths (e.g. below 18 inches). We also found that the spatial distribution of soil water content changes along the crop growing season and that water management zones are not stable in time near the soil surface. Detailed information about this study can be found in Longchamps et al. 2015. The next logical step of this project is to design a methodology that will enable the characterization of soil water content with surrogate data layers such as electrical conductivity or satellite imagery or others.

For our second objective, which consisted of developing an early season precision N management system, we studied the combination of the management zones (soil information) and the active remote sensing (crop information) approaches. Our results indicated that applying variable N rates across the field using an approach integrating information from both soil and crop maintains the yield while reducing N fertilizer consumption, thus enabling higher nitrogen use efficiency (NUE). While this is a positive outcome of the project, we are still investigating the possibilities to increase the NUE by significantly increasing the yield. We hypothesize that by site-specific N applications at multiple growth stages, it may be feasible to significantly increase grain yield.

Our third objective consisted in evaluating variable rate seeding under variable N rates and irrigation rates. This study confirmed our hypothesis that a higher seed rate should be accompanied by higher input rates to reach higher yield. This is among the first studies to demonstrate this type of interaction between seed rate and N or irrigation rates. We thus consider that this is a very interesting finding. However, a lot of questions remain to be answered regarding variable seed populations. What is the effect of soil properties on the optimal seed rate? What is the ideal combination of seed, N and water for each soil types and fertility levels? Although variable seed rate planters are commercially available for farmers, the literature on the subject is sparse and we intend to continue our researches on this subject.

Overall, this project has enabled discoveries in the realm of advanced crop management. We have established a scientifically sound basis for the justification of precision irrigation, we have merged with success two precision N management techniques (i.e. active remote sensing and management zones) that have long been used as standalone practices and we have initiated research in variable seed management, a subject of high interest among producers at the moment. While we have made interesting discoveries and we are many steps closer to finding scientifically sound solutions to improve productivity, profitability and sustainability, many questions have arisen from this project and thus more research will be needed to develop products that are directly transferable to farmers and practitioners.

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