Washington Grain Commission, Wheat and Barley Research Proposal

Project # Continuing Proposal

Title: Precision N Management in Wheat

Researchers: David Huggins, David Brown, Wayne Thompson, Kate Painter

Cooperator: Aaron Esser

Date initiated: July 1, 2015

This is year _3_ of _3_ (maximum 3 years) of the funding cycle.

Justification: Science-based decision aids for the application of precision N management technologies in wheat are lacking including criteria for determining N management zones, precision N application rates and site-specific assessment of wheat performance (crop and economic evaluation).

A. Problem: Despite the availability of powerful precision agricultural technologies such as Global Positioning Systems (GPS), Geographic Information Systems (GIS), yield monitors, satellite remote sensing and variable rate applicators (VRT), there are currently no science-based, site-specific recommendations and limited grower practice of precision N management for dryland wheat in the inland Pacific Northwest (PNW) (Figure 1). During the past year, we interviewed dryland wheat growers (northeastern Oregon, eastern Washington and northern Idaho) practicing precision N management to assess how decisions are currently made with respect to developing a prescription N application map and practicing VRT. These interviews revealed major scientific weaknesses in identifying and evaluating economically suitable N management zones and associated N prescriptions. For example: too many management zones were often established based on intuition; often there was inadequate assessment of both spatial and temporal variability in wheat performance and other spatial data (too few years and/or no clear method of using/integrating yield monitor and/or other data); and little to no evaluation of N prescription performance as compared to “business as usual” was practiced. Clearly, a major barrier to adoption of precision technologies for N management has been the lack of data integration into a science-based, grower-oriented decision support system that includes monitoring, N application and evaluation practices and that optimizes the economic and environmental performance of N fertilizer use. In addition, precision N management strategies for other regions of the country have often been developed for in-crop N adjustments that are reactions to in-season weather conditions (Mamo et al., 2003). These N management strategies are not particularly applicable to crops in Mediterranean-like climates that rely on stored soil water as found in the dryland PNW.

In the case of site-specific N management, successful implementation in the PNW has proven challenging as virtually every factor used for WSU N fertilizer recommendations (e.g. crop yield goals, unit N requirement, soil test N and organic matter levels) has substantial spatial and
temporal field variability (Pan et al., 1997). In the PNW, field variation in wheat grain yield and protein is well documented (Bhatti et al., 1991; Fiez et al., 1994; Yang et al., 1998; Huggins et al., 2010). Large within-field variation in wheat performance arises from landscape and soil attributes that produce variations in available water, organic matter and rooting depth (Busacca and Montgomery, 1992; Huggins and Pan, 2003; Ibrahim and Huggins, 2011). Collectively, these studies show that the strong influence of topographic and soil factors on grain yield, protein and N use efficiency (NUE) could facilitate their prediction and management through the use of precision farming technologies. A major unknown is whether or not the spatial and temporal variability in crop performance and N-related processes can be sufficiently characterized and predicted to enable N management decisions to be tailored to site-specific requirements. Assessing this unknown requires long-term databases that consist of detailed site-specific crop performance and soil data such as the 15-years that are available from studies at the WSU Cook Agronomy Farm.

Poor NUE represents not only a financial loss to the producer, but a serious environmental threat from increased \(N_2O\) emissions, as well as eutrophication and degradation of surface and ground waters via leached \(NO_3^-\). Current strategies for managing N fertilizer in wheat-based dryland farming systems of the PNW were developed on a regional scale for the uniform, whole-field application of N under intensive tillage systems (Leggett, 1959). The inadequacy of current N fertilizer recommendations was first documented at the WSU Cook Agronomy Farm (CAF) near Pullman, WA, where uniform N applications have resulted in large within-field variations in wheat performance (yield and protein), N uptake efficiencies (12 to 48%) and N losses of up to 100% of applied fertilizer N (Huggins et al., 2010). Some consequences of the current approach to N management in dryland wheat production are: (1) insurance applications of N fertilizer designed to reduce the risk of N deficiencies over time and space; (2) sub-optimal N use efficiencies due to N supplies that are over or under crop requirements; (3) unbalanced cropping system N budgets with undesired N leaching and gaseous losses; and (4) lack of direct measures to evaluate N management strategies with respect to NUE and N losses (Huggins and Pan, 2003).

**B. Impact:** Increases in N fertilizer use efficiency will save producers money as well as improve water and air quality. If N management prescriptions can be tailored to site- and time-specific conditions, NUE could be improve by up to 50% (Huggins et al., 2010). Even a 20% savings in N fertilizer use where N applications, for example, are 100 lbs/ac, can translate into 20-30 lbs ($12-18/ac at $0.60/lb N) less applied N/acre. Of course, this economic benefit would be offset by costs of precision farming technology and associated management requirements. Nevertheless, increases in NUE have the potential to have economic and environmental benefits for all classes of wheat grown in the PNW.

The expected outcomes of the project are: (1) on-farm demonstration and testing of precision management technologies and practices with a realistic prognosis for grower adoption; (2) grower-oriented precision N management decision-aid tools that result in greater performance of cereal crops, increased NUE and reduced N losses as compared to uniform N management; and
(3) outreach/extension materials and technical specifications for growers to achieve sound precision N management strategies.

C. Goal: Develop science-based decision aids for the application of precision N management strategies in wheat. Goal accomplished through the integration of crop (e.g. yield monitoring), soil (e.g. apparent electrical conductivity), remote sensed (e.g. Rapid-Eye imagery) and economic data using field-scale studies at the WSU Wilke Farm, WSU Cook Agronomy Farm and on-farm locations.

Process

Objectives will build onto on-going studies at the WSU Wilke Farm and Cook Agronomy Farm that have been funded by USDA over the last 2-3 years by the Site-Specific Climate Friendly Farming project and the Regional Approaches to Climate Change (REACCH) project. In addition, new farms with a history of practicing precision N management have been identified and will be used to aid development and testing of decision tools. The USDA Long-term Agroecosystem Research (LTAR) program will also support these research efforts.

A. Objectives:

Objective 1. Assess spatial variation in wheat performance and related causal factors to enhance precision N decisions. Measure field-scale, site-specific wheat performance and related variables (e.g. yield, protein, economic return, N status, N use efficiency, soil organic matter and inorganic N, soil water availability) required for precision N management decisions at the WSU Wilke, Cook Agronomy Farms as well as from on-farm trials.

Objective 2. Develop science-based criteria for establishing within-field management zones including site-specific evaluation of wheat performance (yield, protein, NUE, economics).

B. Procedures:

Objective 1. At the Wilke farm, precision N management studies were initiated in 2012 and comparisons consist of geo-referenced field strips with two treatments (uniform versus precision N management) with four replications per field. Grid points are established within the strips to hand harvest grain and analyze yield and protein. Soil sampling is targeted to assess treatment differences in N use and loss and remote sensing (Rapid-eye imagery) is being used to help assess spatial differences in treatments. A combine mounted yield monitor is also used to assess crop performance in the two treatments. Differences in crop performance and NUE will be analyzed to provide economic and environmental data for Objective 2. Results from these studies will be used to identify where gains in water, N efficiency or improvements in crop performance can be realized, thereby directing establishment and evaluation of management zones for precision N technology. In 2012-2013, two 26-ac fields at the Wilke Farm were used for a precision N studies and these will now be continued for winter wheat. Grain yield monitor (2 year) and apparent electrical conductivity (Geonics EM-38) data were used to establish three N
management zones with low, medium and high yield goals (Figure 2). Variable rate N was applied during seeding of hard white spring wheat. Overall field averages for the two N application strategies were very similar (Figure 3). The N balance index (N removed in harvested grain divided by N fertilizer applied) was greater for VRT (0.99) as compared to the Uniform (0.82) treatment. Preliminary economic analyses show that the VRT strategy was more economical on 3 of 4 “high” zones and 2 of 3 “low” zones. Other data still under assessment include field soil water and inorganic N from comparative point samples as well as satellite imagery. These data will be used to further assess N and water use efficiency as well as the effectiveness of defining the three VRT zones. We repeated a similar experiment on this field as well as another field at the Wilke Farm in 2013 and the proposed project will continue these studies with winter wheat for years (2014-15).

At the CAF, a similar field-scale study will consist of strips with two N management treatments: (1) uniform application of N fertilizer based on WSU guidelines; and (2) site-specific N management based on the spatial patterns of yield, terrain and soil variables. Control points with 0 applied N will be strategically placed at geo-referenced topographic positions. Treatments will be established for winter wheat. Crop and soil sampling will be at historically established geo-referenced locations and components of N use efficiency will be assessed using methods described by Huggins and Pan, (2003). Site-specific N management will be compared to current WSU guidelines for N management in field-scale experiments. Consequently, we will test the null hypothesis of precision N management: given the large temporal and spatial variation in within-field crop yield and N-related processes, the optimal risk aversion strategy is uniform N management.

On-farm research will be coordinated with Wayne Thompson, WSU Cropping Systems Agronomist. Here, a field trial was established in fall, 2014, that consists of across-field strips of applied N. Five rates of N were used and data analyses will provide information on yield response curves to applied N across the field.

Objective 2. Precision N management zone development will key on economic, yield, N and water use efficiency criteria at all locations from data collected under Objective 1. Enterprise budgets will be developed comparing uniform and precision N management to assess the costs of the technology, differences in N fertilizer inputs and crop performance and to determine various economic risks and strategies associated with the adoption of the technology. At the WSU Cook Agronomy Farm, yield and economic data collected from 369 geo-referenced points (2 m²) in a nonaligned, randomized, 100x100 ft grid over 92 acres of the CAF from 1999-2013 will be analyzed to assess similarities in year-to-year spatial structure using variography (Rossi et al., 1992). Preliminary analyses have shown promising year-to-year consistency in the spatial variation of relative yields of wheat and other crops in certain portions of the field. In addition, precision N farming strategies currently being used at on-farm locations will be assessed using farmer owned equipment and technology including evaluation of the effectiveness of the precision N treatment using “business as usual” N strips.
Decision-aid products will be developed for: (1) using yield monitor and relevant terrain and soil data to establish realistic crop performance goals; (2) targeting soil sampling in precision farming systems to assess soil N availability; (3) determining site-specific N management zones and prescriptions; and (4) assessing economic and environmental trade-offs for precision N management.

C. Cooperation and Coordination: Dr. Dave Huggins will provide overall research and outreach coordination and expertise on precision N management as well as WSU Cook Agronomy Farm collaboration. Dr. David Brown will provide expertise in spatial statistical analyses, remote sensing and decision support products. Mr. Wayne Thompson will provide expertise on precision agricultural technology, decision support products, southeast WA precision farming collaborators, as well as outreach activities and products. Dr. Kate Painter will provide agricultural economic expertise and assessment of precision N management. Aaron Esser will aid with WSU Wilke Farm collaboration as well as outreach activities and products.

D. Review: We will promote awareness of precision agriculture principles (e.g., assessing spatial and temporal yield variability and principles of precision management) and report research progress at the Wheat Research Review, regional scientific and stakeholder conferences and workshops, articles in *Wheat Life*, field days (Cook, PCFS), grower meetings (organized by county extension agents and ag companies) and by phone or by email as requested. Results will also be published in scientific journals and presented at scientific congresses.

E. Location(s): WSU Wilke Farm; WSU Cook Agronomy Farm; Other WA farms including Columbia Co. Farms to be identified.

Budget

1. Amount allocated by the Commission in fiscal year (FY) 2016: $900.00

2. Amount requested for FY 2017 (July 1, 2016-June 30, 2017):

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\(^1\) Salary for support of Associate in Research.
Figures

Figure 1. Successful application of precision farming requires that advanced field diagnostics and precision application technologies are coupled with science-based decision support systems at within-field scales.

Figure 2. Grain yield monitor and apparent electrical conductivity data used to create N management zones (right) with high (green), medium (yellow) and low (red) yield goals at the WSU Wilke Farm. Control strips with uniform applications of N depicted in gray.
Figure 3. Yield goals, applied N and resultant yield and grain protein concentration at the WSU Wilke Farm study. Actual yield and protein for field zones on far right with a comparison between uniform (Uni) and variable rate (VRT) N application.

References


F. Outcomes: 
**Evaluation of Variable Rate Nitrogen Application in Dryland Winter Wheat**

Sub-field N management zones were created for three field sites in the inland Pacific Northwest Palouse region using yield and electrical conductivity (ECa) data, a method that reflected current grower practices. Significant differences in N use efficiency, N uptake efficiency, and N utilization efficiency ranged from 0% to increases of over 30%, 17%, and 25%, respectively. Spatial variability in grain protein response to N, and increases of 1% were observed as N fertilizer increased. Grain yield response to N fertilizer was small and significant differences were only observed between points that received starter fertilizer only and points receiving applied rates of 9 lbs/ac. Varying N rates at these sites was most effective in areas of the field that were defined as low yielding zones. Here decreasing N fertilizer application decreased potential N losses and money spent without taking yield penalties. Increasing N rates in zones defined as high yielding did not improve yield and decreased N use efficiency, thereby increasing the potential for N losses and decreasing financial profits.

**Management Zone Delineation Based on N Use Efficiency Performance: a Decision-Support and Evaluation System for Precision N Applications**

Grain yield, protein, and other performance criteria were measured and calculated at grouped points receiving variable rates of N fertilizer. Performance classification criteria were created that reflected crop performance goals regarding maximum yield and N uptake efficiency. Groups were classified based on 4 performance criteria to identify areas of the field that performed similarly. Different N rates were then analyzed for N management zones created using clustering and performance classification criteria. Results of the clustering analysis and performance zone classification only captured significant differences between zones at one of the two sites. At the site where differences between zones were significant, grain protein ranged from 8.2% to 11.6% and N use efficiency increased by 81% to 118% from highest N rate to the lowest across all zones. Performance class zones captured similar responses to N rates across all performance classes. The development of management zones based on performance criteria provides basis for the creation of management zones and the evaluation of N fertilizer decisions made within those management zones. The advantages to this method are in the management interpretation of performance classes as well as detailed evaluation of VR decisions increasing crop performance with regards to yield and protein as well as NUE and NUE component measurements.