Sensor-based Topdressing for Winter Wheat

Peter Scharf
Plant Sciences Division, University of Missouri
Collaborator: Newell Kitchen
USDA Agricultural Research Service, Columbia, MO

Objective:
- Develop reliable sensor interpretations as a basis for on-the-go variable-rate N topdressing of winter wheat.
  - Evaluate existing and emerging interpretation systems from Oklahoma State University/NTech, University of Missouri, and University of Kentucky.
  - Explore possible new interpretation systems that might perform better than existing/emerging systems.

Relevance:
- Wheat yield is sensitive to both under-supply and over-supply of N.
  - Economic penalty for being wrong in either direction.
  - Precision agriculture tools are most useful in this type of situation.
- We found that the economically best N rate varied widely in 7 of 8 Missouri corn fields in 3 regions. It is likely that the same is true for wheat. A way to manage this variability might increase profitability of wheat production.
- Uniform applications in variable fields means that there will be areas of both over-application and under-application, reducing yield and profit.
- Our research suggests that crop color is much more reliable for indicating the amount of N needed than yield goal, soil tests, or landscape variables.
- Sensors can measure crop color and control N rate on the go. We have extensive experience working with this system in corn, including 92 on-farm demonstrations from 2004-2008 (see photo).
- Sensors could easily be incorporated into existing topdress practices of Missouri wheat producers.
- Missouri NRCS has recently approved sensor-based sidedressing of corn as a nutrient management practice that qualifies for program support. They are interested in approving this practice for topdressing of wheat as well, but more research is needed before they can be confident that it will work.
- Producers will likely need support in adopting these systems, creating a business opportunity for the fertilizer industry.
Procedures:
- Trials will be located in central Missouri on claypan soils near Columbia and Centralia.
- At least three trials will be run each year on different fields, or at different landscape positions in the same field.
- Most trials will be designed to provide flexibility for both evaluating existing systems and developing new ways to translate sensor readings into N rate recommendations.
  - Plots will receive either 0, 30, 60, 90, 120, or 150 lb N/acre.
  - Sensor readings taken pre-joint with two different types of sensor:
    - Crop Circle active light sensors (Holland Scientific)
    - Greenseeker active light sensors (N-Tech)
- Regression analysis will be used to estimate a nitrogen response function for each trial.
  - Response functions will be used to calculate optimal N rate, which will be regressed against sensor reflectance values to suggest possible new systems for interpreting sensor readings.
  - Response functions will also be used to calculate yields that would be associated with the N rate recommended by each existing system.
    - Yield and N cost associated with each system can be compared.
- Some trials may also apply actual variable N rates, to compare outcomes from several existing or emerging variable-N interpretation systems:
  - A sensor-based recommendation system developed at Oklahoma State University and currently marketed by N-Tech.
  - The Oklahoma system modified based on research in Kentucky and/or Virginia (gives higher N rates; Oklahoma system was too conservative for the higher-yield environments found in Kentucky and Virginia, which are similar to Missouri).
  - An experimental sensor-based recommendation system based on research at the University of Missouri.
  - 90 lb N/acre, representing a typical topdress rate used by wheat producers.
- Four or more replications will be used in each trial.

Current status and importance of sensor-based topdressing for winter wheat:
- Our research has shown that spatial variability in soil N supply complicates fertilizer management for corn. The same is probably true for wheat. Systems are needed to deal with this variability and avoid under- and over-application.
- Sensor-based topdressing could help manage this variability in soil N.
- Murdock and others at the University of Kentucky have shown that wheat N need can be predicted based on plant color measured with a hand-held chlorophyll meter that clamps on individual leaves.
  - This proves the concept that wheat N rate can be predicted from color, but this meter is too slow, labor-intensive, and hard on the knees to be used to manage large areas.
- Research at Oklahoma State University produced a sensor-based topdressing system that is currently marketed by N-Tech based on their Greenseeker brand sensors.
  - Oklahoma research suggests that this system can improve wheat profitability, though few producers or retailers have yet adopted it.
• Research at other universities (Virginia Tech, University of Kentucky) suggests that although the Oklahoma system has promise, it needs to be modified considerably to be successful in humid climates.
  ○ The system often under-applies N in humid-region wheat, where yields are higher than in Oklahoma.
• Crop Circle brand sensors have performed well in our corn experiments and demonstrations and will be included in this project. These sensors will be distributed by Ag Leader starting in 2009.
• Toshiba has re-engineered the Hydro/Yara sensor that has been available in Europe for over ten years and is looking to take it to market. We will try to get a prototype of this sensor to use in our experiments.
• We have developed equations for converting sensor readings to N rates for corn and cotton. We can leverage this experience into efficient development of sensor interpretations for wheat.
• In many ways, wheat is the ‘best fit’ crop for N management using crop color sensors.
  ○ More complete soil cover at the time of fertilizer application.
  ○ Normal management includes fertilizer application to the growing crop just prior to rapid growth.

Timetable:
February 2009 Select experimental locations and put out high-N reference areas.
March 2009 Take readings with two or three different models of reflectance sensors.
  Apply N rate treatments.
June 2009 Harvest experiments.
July-Sept 2009 Analyze results
2010, 2011 Repeat 2009 timetable

Strategy for application/transfer of knowledge:
Our main strategy for transfer of knowledge will be to support interested producers and service providers in testing these systems, as we have done with corn. This support might include consultation, loan of sensors and computers, and help with interpreting outcomes. If these systems are performing well, we will also pursue funds to hire one or two additional people to work on technology transfer and to help farmers to try out the systems that we are developing.

In addition to supporting early adopters, we will build educational programs for producers and agribusiness personnel to help them understand how these systems work, what their advantages and disadvantages are (including experiences and results of early adopters), and what is needed to succeed in applying them. Scharf has an Extension appointment and his time will go to presenting results at Extension conferences, field days, and winter meetings. Programs will also be delivered through regional extension specialists, newsletters, farm press, press releases, and the internet.
Budget:
- Larry Mueller is a Research Specialist with seven years experience in this program, an Ag Systems Management degree, expertise in plot experiments and equipment, and who has been an important part of our team in sensor research for corn.
- He will be responsible for most aspects of this project, including site selection, plot design and layout, treatment application, collecting and processing sensor readings, and harvest. He will also do much of the data analysis with help from Scharf and Kitchen.
- We already own the sensors that will be used in the project (purchased from corn research projects). Purchase price of the sensors was approximately $10,000. A ruggedized tablet computer ($3,000) is available for data collection, and we have developed custom software that allows collection of data from all sensor types into a single computer. A custom-built plot-size dry fertilizer applicator (boom, blower) will be used for small plots and a Gandy metering dry fertilizer applicator with a Raven controller will be used if we do large variable-rate N strips. All of these items are available for use in this project as our in-kind contributions.

Budget summary:
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<th>Item</th>
<th>Amount</th>
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<tr>
<td>Larry Mueller 40%</td>
<td>16,900</td>
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<td>Benefits (31%)</td>
<td>5,240</td>
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<td>Fertilizer and other supplies</td>
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<td>Total request for 2009</td>
<td>$23,140</td>
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<td>3-year total request</td>
<td>$69,420</td>
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Peter Clifton Scharf
Nutrient Management Specialist and Associate Professor
Plant Sciences Division
210 Waters Hall
University of Missouri
Columbia, MO 65211

Research and Extension education interests
• developing, evaluating, and promoting tools to predict crop N needs, including variable-rate N management
• evaluating N management alternatives including source and timing
• minimizing environmental impacts of agricultural nutrients
• coordinated management of soil, fertilizer, and manure nutrients
• tailoring fertilizer and lime recommendations to account for soil properties
• economic comparisons of production alternatives

Education

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<tr>
<th>Degree</th>
<th>Date</th>
<th>Institution</th>
<th>Major</th>
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<tr>
<td>Ph.D.</td>
<td>May 1993</td>
<td>Virginia Polytechnic Inst. and State University</td>
<td>Crop &amp; Soil Environmental Sciences</td>
</tr>
<tr>
<td>M.S.</td>
<td>July 1988</td>
<td>Virginia Polytechnic Inst. and State University</td>
<td>Agronomy</td>
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<tr>
<td>B.S.</td>
<td>August 1982</td>
<td>University of Wisconsin</td>
<td>Biochemistry, Genetics</td>
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Recent Research Publications
Recent Extension Publications


Scharf, Peter. 2008. Drainage installation field day to be held in July. Integrated Pest & Crop Management 18:75.


Curriculum Vitae
Newell R. Kitchen, USDA-ARS Soil Scientist

Education:
1984   B.S.  Brigham Young University (Agronomy)
1986   M.S.  University of Missouri (Agronomy)
1990   Ph.D.  Colorado State University (Agronomy/Soil Science)

Professional Positions:
1990-1996 Research Assistant Professor, Soil and Atmospheric Sciences Dept,
      University of Missouri, Columbia, MO
1996- current Soil Scientist, USDA-ARS, Cropping Systems and Water Quality
      Research Unit, Columbia, MO
1996-2003 Adjunct Assistant Professor, University of Missouri, Columbia, MO
2003- current Adjunct Associate Professor, University of Missouri, Columbia, MO

Professional Society Membership:
American Society of Agronomy
Soil Science Society of America
Soil and Water Conservation Society
Certified ARCPACS Professional Soil Scientist

Honors and Awards:
J. Fielding Reed Potash and Phosphate Institute Fellowship, 1989
USDA Outstanding Performance Award, 2001, 2004, 2005
Robert E. Wagner Potash and Phosphate Institute Award (Jr. Scientist), 2003

Professional Society Service:
Active member attending 20 ASA-SSSA-CSA annual meetings between 1982-2005.
  Presented at least 1 paper each year and authored/co-authored as many as 8 papers
  per year. 51 total papers authored/co-authored at annual meetings. Chaired oral
Special Editor for six 2000 ASA meeting symposium manuscripts on Application of Soil
Electrical Conductivity in Precision Agriculture, May-June, 2003, Agron. J.
Chair (by election), Integrated Agricultural Systems Division, ASA, 2001
Board Rep. (by election), Integrated Agricultural Systems Division, ASA, 2005-2008
Editorial Board Member, Journal of Precision Agriculture, 2001-present
Editor for a special issue of Computers and Electronics in Agriculture J. on the topic of
Emerging Technologies For Real-time Integrated Agriculture Decisions, current.

Achievements in Teaching and Extension:
Graduate Students Advisor,  6 MS and 4 PhD students
Graduate Student Committee Member, 4 MS and 5 PhD students
Co-organizer of course entitled Precision Agriculture Science and Technology, listed
    through 3 departments at the University of Missouri. Dr. Kitchen helped team-teach
the class (Kitchen ~ 30%) for 4 years (1997-2000, 2003) and taught the class for 2 years (2001-2002). Enrollment: 20-30/year.


**Professional Contributions:**

- Book chapters .......................................................... 3
- Technical papers, refereed........................................... 45
- Technical papers, non-refereed................................. 65
- Non-technical papers............................................... 24
- Patents ........................................................................ 0
- Invited lectures, seminars or symposia presentations........ 36
- Other related oral, written, visual presentations or products.. 93

**Recent Refereed Publications:**


