Sensor-based Topdressing for Winter Wheat

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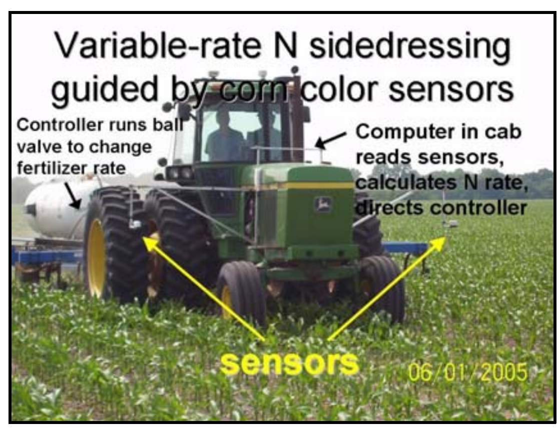
Collaborator: Newell Kitchen
USDA Agricultural Research Service, Columbia, MO

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.



We have done 92 field-scale demos of sensor-guided sidedressing for corn in Missouri.

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:

Larry Mueller 40%	16,900
Benefits (31%)	5,240
Fertilizer and other supplies	1,000
Total request for 2009	$23,140
3-year total request	$69,420

Peter Clifton Scharf

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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

Degree	*Date*	*Institution*	*Major*
Ph.D.	May 1993	Virginia Polytechnic Inst. and State University	Crop & Soil Environmental Sciences
M.S.	July 1988	Virginia Polytechnic Inst. and State University	Agronomy
B.S.	August 1982	University of Wisconsin	Biochemistry, Genetics

Recent Research Publications

Nelson, K. A., Scharf, P. C., Bundy, L. G., and Tracy, P. 2008. Agricultural management of enhanced-efficiency fertilizers in the north-central United States. Online. Crop Management doi:10.1094/CM-2008-0730-03-RV.

Hong, N., P.C. Scharf, J.G. Davis, N.R. Kitchen, and K.A. Sudduth. 2007. Economically optimal nitrogen rate reduces residual soil nitrate. J. Environ. Qual. 36:354-362.

Scharf, P.C., N.R. Kitchen, K.A. Sudduth, and J.G. Davis. 2006. Spatially variable corn yield is a weak predictor of optimal nitrogen rate. Soil Sci. Soc. Am. J. 70:2154-2160.

Scharf, P.C., S.M. Brouder, and R.G. Hoeft. 2006. Chlorophyll meter readings can predict nitrogen need and yield response of corn in the north-central U.S. Agron. J. 98:655-665.

Scharf, Peter C., Newell R. Kitchen, Kenneth A. Sudduth, J. Glenn Davis, Victoria C. Hubbard, and John A. Lory. 2005. Field-scale variability in optimal N fertilizer rate for corn. Agron. J. 97:452-461.

Recent Extension Publications

Scharf, Peter and John Lory. 2006. Best Management Practices for nitrogen fertilizer in Missouri. 12 p. MU Extension publication IPM1027.

Lory, John and Peter Scharf. 2008. Rescue nitrogen applications on corn can still be profitable. Integrated Pest & Crop Management 18:80.

Scharf, Peter. 2008. Soil samples show nitrogen loss. Integrated Pest & Crop Management 18:74.

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

Scharf, Peter. 2008. Nitrogen loss scoresheet. Integrated Pest & Crop Management 18:68.

Lory, John and Peter Scharf. 2008. Is my nitrogen still there? Integrated Pest & Crop Management 18:27,35.

Scharf, Peter and David Dunn. 2008. Nitrogen loss in wheat. Integrated Pest & Crop Management 18:22,25.

Scharf, Peter. 2008. Nitrogen prices through the roof again. Integrated Pest & Crop Management 18:25.

Scharf, Peter and David Dunn. 2008. Potential for N loss with heavy rains on wheat. Mid-America Farmer Grower, March 25, 2008, p. 13.

Rich, Doug. 2008. Challenging times put a premium on research. High Plains Journal, March 12, 2008. Using information from Peter Scharf.

Oltman, Brian. 2008. Wheat N timing. Ag Professional, Jan. 2008. Using information from Peter Scharf.

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 Superior Performance Awards, 1998, 1999, 2000, 2002, 2003
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 paper sessions in 1997, 2000, 2001, 2002, 2003, 2005.
Served a three-year appointment (1997-1999) as Asso.Editor for Agronomy Journa.
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.

Invited presenter at regional and national extension workshops and conferences. Examples include: *Information Agriculture Conferences*, 1996, 2001; *North Central Extension-Industry Soil Fertility Conference*, 1992, 1995, 1998, 2000, 2001, 2003, 2005; ASAE-sponsored *Agricultural Equipment Technology Conference*, 2003, Louisville, KY.

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:

Kitchen, N.R., S.T Drummond, E.D. Lund, K.A. Sudduth, and G.W. Buchleiter. 2003. Soil electrical conductivity and topography related to yield for three contrasting soil-crop systems. Agronomy Journal: 95:483-495.

Scharf, P.C., J.P. Schmidt, N.R. Kitchen, K.A. Sudduth, S.Y. Hong, J.A. Lory, and J.G. Davis. 2003. Remote sensing for nitrogen management. Journal of Soil and Water Conservation: 57:518-524.

Sudduth, K.A., N.R. Kitchen, G.A. Bollero, and D.G. Bullock. 2003. Comparison of electromagnetic induction and direct sensing of soil electrical conductivity. Agronomy Journal: 95:472-482.

Wang, F., C.W. Fraisse, N.R. Kitchen, and K.A. Sudduth. 2003. Site-specific evaluation of the CROPGRO-soybean model on Missouri claypan soils. Agricultural Systems Journal: 76:985-1005.

Wang, D., A.A. Prato, Z. Qiu, N.R. Kitchen, and K.A. Sudduth. 2003. Economic and environmental evaluation of variable rate nitrogen and lime application for claypan soil fields. Journal of Precision Agriculture: 4:35-52.

Fridgen, J.J., N.R. Kitchen, K.A. Sudduth, S.T. Drummond, W.J. Wiebold, and C.W. Fraisse. 2004. Management Zone Analyst (MZA): Software for sub-field management zone delineation. Agronomy Journal 96:100-108.

Officer, S.J., A. Kravchenko, G.A. Bollero, K.A. Sudduth, N.R. Kitchen, W.J.Wiebold, H.L. Palm, D.G. Bullock. 2004. Relationships between soil bulk electrical conductivity and the principal component analysis of topography and soil fertility values. Plant and Soil: 258: 269-280.

Hong, S.Y., K.A. Sudduth, N.R. Kitchen, C.W.Fraisse, H.L. Palm, and W.J. Wiebold, 2004. Comparison of remote sensing and crop growth models for estimating within-field LAI variability. Korean J. of Remote Sensing, 20(3):175-188.

Sudduth, K.A., N.R. Kitchen, W.J. Wiebold, W.D. Batchelor, G.A. Bollero, D.G. Bullock, D.E. Clay, H.L. Palm, F.J. Pierce, R.T. Schuler, and K.D. Thelen. 2005. Relating apparent electrical conductivity to soil properties across the north-central USA. Comp. and Electronics in Agric. 46:263-284.

Kitchen, N.R., K.A. Sudduth, D.B. Myers, S.T. Drumond, S.Y. Hong. 2005. Delineating productivity zones on claypan soil fields using apparent soil electrical conductivity. Comp. and Electronics in Agric. 46:285-308.

Scharf, P.C., N.R. Kitchen, K.A. Sudduth, J.G. Davis, V.C. Hubbard, and J.A. Lory. 2005. Field-scale variability in economically-optimal N fertilizer rate for corn. Agron. J. 97:452-461.

Jung, W.K., N.R. Kitchen, K.A. Sudduth, R.J. Kremer, and P.P. Motavalli. 2005. Relationship of apparent soil electrical conductivity to claypan soil properties. Soil Science Society Journal 69:883-892.

Ghidey, F., P.E. Blanchard, R.N. Lerch, N.R. Kitchen, E.E. Alberts, E.J. Sadler. 2005. Measurement and prediction of herbicide transport from the corn phase of three cropping systems. Journal of Soil and Water Conservation 60(5): 260-273.

Jung, W., N.R. Kitchen, K.A. Sudduth, and S.H. Anderson. 2006. Spatial characteristics of claypan soil quality properties of an agricultural claypan soil. Soil Science Society of America Journal 70:1387-1397.

Lerch, R.N., N.R. Kitchen, R.J. Kremer, W.W. Donald, E.E. Alberts, E.J. Sadler, K.A. Sudduth, D.B. Myers, and F. Ghidey. 2005. Development of a conservation-oriented precision agriculture system: Water and soil quality assessment. Journal of Soil and Water Conservation 60 (6): 411- 421.

Kitchen, N.R., K.A. Sudduth, D.B. Myers, R.E. Massey, E.J. Sadler, R.N. Lerch, J.W. Hummel, and H.L. Palm. 2005. Development of a conservation-oriented precision agriculture system: Crop production assessment and plan implementation. Journal of Soil and Water Conservation 60(6):421-430.

Scharf, P.C. N.R. Kitchen, K.A. Sudduth, and J.G. Davis. 2006. Spatially variable corn yield is a weak predictor of optimal nitrogen rate. Soil Science Society of America Journal 70:2154-2160.

Hong, N., P.C. Scharf, J.G. Davis, N.R. Kitchen, and K.A. Sudduth. Economically optimal nitrogen rate reduces soil residual nitrate. Journal of Environmental Quality. (accepted)

Jiang, P., S.H. Anderson, N.R. Kitchen, E.J. Sadler, and K.A. Sudduth. Landscape and conservation management effects on hydraulic properties on a claypan-soil toposequence. Soil Science Society of America Journal. (accepted).

Jung, W., N.R. Kitchen, S.A. Anderson, and E.J. Sadler. 200X. Crop management effects on water infiltration for claypan soils. Journal of Soil and Water Conservation, (accepted)