Title: **Optimal Placement of Nitrogen Fertilizer Sources to Improve Nitrogen Use Efficiency in Corn**

Investigators: Peter Motavalli, Dept. of Soil, Environ., and Atmos. Sci., Univ. of Missouri
Kelly Nelson, Div. of Plant Sciences, Univ. of Missouri, Novelty, MO

Objectives and Relevance:

Recent efforts to improve nitrogen (N) use efficiency in corn production have focused on several management strategies including changes in crop genetic traits (Hirel et al., 2011), N fertilizer source (Nelson et al., 2008), timing and method of fertilizer application (Nash et al., 2013), and the spatial placement of N fertilizer in soil (Drury et al., 2006) or across agricultural fields (Motavalli et al., 2012; Roberts et al., 2012). These strategies are designed to enhance plant N availability at critical growth stages and to minimize environmental N losses.

Research in Missouri has indicated that strip tillage and deep banding of N fertilizer to a depth of 6 inches increased corn yields 25 to 86 bu/acre compared to no-till, broadcast surface application of N fertilizer (Nash et al., 2013). The strip-till and deep placement system also significantly reduced cumulative environmental N losses in the form of nitrous oxide gas per unit yield compared to the no-till/surface application system (Nash et al., 2012). Possible explanations for increased yields with deep banded placement of N fertilizer include the closer proximity of the N fertilizer to roots for plant uptake. In addition, this N placement could lower the potential for gaseous N losses due to greater physical impediments to gas movement to the soil surface and decreased soil organic matter and soil microbial activity with depth that are necessary for certain N loss processes such as nitrification and denitrification (Grant et al., 2010). Soil water content and temperature may also vary with greater soil depth.

Additional studies have observed decreased gaseous N loss with greater depth of urea or UAN fertilizer application (Liu et al., 2006; Khalil et al., 2009) but other studies have found a contrasting result. For example, Drury et al. (2006) observed a 26% increase in cumulative nitrous oxide emission when N fertilizer was placed at a depth of 4 inches compared to when the fertilizer was placed at a 1 inch depth. Under semi-arid, irrigated conditions, Halvorsen and Del Grosso (2013) found no differences in corn yield with banded versus broadcast N fertilizer and higher nitrous oxide emissions when the fertilizer was banded. These mixed results may possibly be due to differences in climate and soil properties among the study locations.

Utilization of enhanced efficiency N fertilizer sources, such as polymer-coated urea and urea with urease and nitrification inhibitors, have been extensively researched in the North-Central United States and Missouri as a management practice to increase N use efficiency (Nelson et al., 2008). Use of these N fertilizer sources and treatments has been often most successful in poorly-drained soils or soils with high leaching potential (Nelson et al., 2008). Deep banding urea fertilizer with a nitrification inhibitor may further reduce the potential denitrification and nitrate leaching losses that might occur with this form of N fertilizer application, thereby increasing N use efficiency and crop yields.

The proposed objectives of this study are to: 1) determine the effectiveness of different N fertilizer placement practices including deep banding urea or urea plus a nitrification inhibitor on

corn yields and N use efficiency in a poorly-drained claypan soil, and 2) assess the differences in cumulative soil nitrous oxide gas emissions with deep banding and other N fertilizer placement strategies.

Procedures:

- A three-year field experiment will be established in Northeastern Missouri at the Greenley Research Center on a poorly-drained soil. The experimental design will be a randomized complete block design with five replications. Treatments will include pre-plant deep banding of urea or urea plus a nitrification inhibitor (NI) (Instinct®, Dow AgroSciences) at a depth of 8 inches compared to pre-plant urea broadcast surface-applied or incorporated to a depth of 6 inches. The fertilizer application rate will be 180 lbs N/acre and we will include a non-treated control.
- The deep banded N fertilizer treatment will be accomplished with a custom designed strip-till conservation C-jet unit. Nitrogen fertilizers will be banded to a depth of 8 inches below the planted row with fertilizer delivered using a Montag (Montag Manufacturing, Inc., Emmetsburg, IA) dry fertilizer air delivery system. After the banded fertilizer application, the entire soil surface will be surface tilled to remove the possible effects of strip tillage on crop response.
- Soil samples will be collected periodically in the band at depths of 0-5, 5-10, and 10-15 inches to determine changes in soil inorganic nitrogen (ammonium and nitrate) over the growing season. Soil bulk density will be determined at the same depths using the core method to allow for conversion of the soil nitrogen results into lbs N/acre.
- Corn N status will be monitored periodically using a SPAD meter (chlorophyll index meter).
- Corn yields will be determined using a two-row combine and N uptake determined by harvesting one row for silage dry weight yield and total N tissue analysis. Nitrogen recovery efficiency will be calculated based on the difference in N uptake between the treated and the control plots divided by the total N fertilizer applied.
- Assessment of cumulative soil nitrous oxide losses with the different N fertilizer placement treatments will be determined using a vented, non-steady state closed chamber technique (Nash et al., 2012) and measurement of evolved nitrous oxide gas using a gas chromatograph. Frequent sampling of the chambers will occur over the growing season to determine nitrous oxide flux and then cumulative nitrous oxide emissions calculated based on the observed fluxes. A soil sample will be collected to a depth of 4 inches at the time of gas sampling to determine soil surface gravimetric water content and temperature at a depth of 2 inches. An Onset Hobo datalogger will also be installed to monitor diurnal changes in soil temperature and volumetric water content at soil depths of 2, 6, 10, 14, 18, 22, and 26 inches.

Current Status and Importance of Research:

Improvements in N use efficiency in corn are important in Missouri especially in areas prone to N loss such as poorly-drained soils. Prior research has indicated that enhanced efficiency N fertilizers may be effective in these soils in wet areas of fields or when rainfall is relatively high (Nelson et al., 2008). These wet soil conditions also promote high N losses primarily through surface runoff or gaseous N loss. Deep banded placement of N fertilizer

placement combined with an enhanced efficiency N fertilizer may be important to reduce the conditions for high N losses thereby improving corn yields. However, research in other locations outside of Missouri in better drained soils have shown mixed results for the effectiveness of banding N fertilizer. Therefore, more research is warranted to determine if this management practice is a viable option for Missouri corn growers.

Expected Economic Impact:

The average annual value of Missouri corn production between 2006 and 2010 was approximately $1.6 billion and, therefore, it is a major revenue source for the state. For this reason, cost-effective improvements in corn production practices are a high priority. Moreover, the U.S. Environmental Protection Agency (USEPA) has proposed a 45% reduction in nitrogen and phosphorus loads to the Gulf of Mexico in order to reduce the size of the hypoxic zone to 5,000 km^2 (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, 2008). The projected cost to achieve this reduction will be approximately $9 billion per year (Whittaker et al., 2014) and corn-producing states in the Mississippi River watershed are actively seeking recommendations for management practices that achieve reductions in N and P loss, but also maintain crop production. Therefore, information on improved N fertilizer management practices to maximize corn production and minimize environmental losses is needed so that growers can make informed fertilizer management decisions.

Timetable for Proposed Research:

March-April, 2015	Establish field experiment area
April-May, 2015	Apply N treatments and plant corn
April-Sept., 2015	Sample soils
Sept./Oct, 2015	Harvest experiments
November, 2015	Analyze research results
December, 2015	Submit annual progress report
Feb-Nov. 2016	Same as 2015
December 2016	Submit annual progress report
Feb-Nov. 2017	Same as 2016
December 2017	Submit final report

Strategy for Application/Transfer of Knowledge:

The information developed from this research will be useful for Missouri farmers to make informed decisions on N fertilizer management in poorly-drained soils. Moreover, it will provide some quantitative information on actual environmental N gas losses. This information will be incorporated into research and extension publications, workshops and annual field days to provide additional information to farmers on effective N fertilizer management practices. This project will also provide an opportunity for the training of a graduate student in preparation for a possible future professional career in a soil fertility and plant nutrition-related field in the private or public sector.

Proposed Budget:

CATEGORIES	YEAR ONE	YEAR TWO	YEAR THREE	TOTAL
A. Salaries				
Ph.D. Graduate Research Assistant (50%)	$17,357	$17,878	$18,414	$53,649
B. Fringe Benefits				
Fringe for graduate student	$3,049	$3,140	$3,234	$9,423
TOTAL SALARIES AND FRINGE BENEFITS	$20,406	$21,018	$21,648	$63,072
C. Travel				
Travel to field site	$672	$672	$672	$2,016
Travel to professional meeting	$0	$1,000	$1,000	$2,000
TOTAL TRAVEL COSTS	$672	$1,672	$1,672	$4,016
D. Equipment	$0	$0	$0	$0
TOTAL EQUIPMENT COSTS	$0	$0	$0	$0
E. Other Direct Costs				
Laboratory reagents and supplies	$3,000	$3,000	$3,000	$9,000
Field supplies	$2,000	$2,000	$2,000	$6,000
Soil analysis	$500	$500	$500	$1,500
Publications/Documentation	$0	$500	$500	$1,000
TOTAL OTHER DIRECT COSTS	$5,500	$6,000	$6,000	$17,500
TOTAL REQUEST	$26,578	$28,690	$29,320	$84,588

Justification:
Salaries and Fringe Benefits: Funds are requested for support of a graduate research assistant (50% time) based on set rates at the University of Missouri. Fringe benefits for the graduate student cover the cost of health insurance.

Travel: Covers cost of travel to Greenley Farm and to farm site at a rate of 52.5 ¢/mile. In the second year, $1,000 and in the third year $1,000 are requested to cover cost of travel and board for one researcher to attend a professional conference for presentation of results.

Laboratory Reagents and Supplies: Covers cost of laboratory reagents, sample containers, and other materials used in soil and plant tissue analyses.

Field Supplies: Cost of fertilizer, seed, plot preparation, planting, weed control and harvesting, soil samplers, flags, pots and other field supplies and operations.

Soil Analysis: Covers cost of drying, grinding and analysis of soil samples at the University of Missouri Soil and Plant Testing Laboratory.

Publications/Documentation: Defrays cost of publication and documentation of results and conclusions.

References Cited:

Drury, C.F., W.D. Reynolds, C.S. Tan, T.W. Welacky, W. Calder and N.B. McLaughlin. 2006. Emissions of nitrous oxide and carbon dioxide: influence of tillage type and nitrogen placement depth. Soil Sci. Sco. Am. J. 70:570-581.

Grant, C.A., D.A. Dirksen, D. McLaren, and R.B. Irvine. 2010. Nitrogen fertilizer and urease inhibitor effects on canola emergence and yield in a one-pass seeding and fertilizing system. Agron. J. 102:875-884.

Halvorsen, A.D., and S.J. Del Grosso. 2013. Nitrogen placement and source effects on nitrous oxide emissions and yields of irrigated corn. J. Environ. Qual. 42:312-322.

Hirel, B., T. Tétu, P.J. Lea, and Frédéric Dubois. 2011. Improved nitrogen use efficiency in crops for sustainable agriculture. Sustainability 3:1452-1485.

Khalil, M.I., F. Buegger, M. Schraml, R. Gutser, K.G. Richards, and U. Schmidhalter 2009. Gaseous nitrogen losses from a cambisol cropped to spring wheat with urea sizes and placement depths. Soil Sci. Soc. Am. J. 73:1335-1344.

Liu, X.J., A.R. Mosier, a.D. Halvorsen, and F.S. Zhang. 2006. The impact of nitrogen placement and tillage on NO, N_2O, CH_4, and CO_2 fluxes from a clay loam soil. Plant Soil 280:177-188.

Mississippi River/Gulf of Mexico Watershed Nutrient Task Force. 2008. Gulf Hypoxia Action Plan 2008 for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico and Improving Water Quality in the Mississippi River Basin. Washington, DC.

Motavalli, P.P., K.A. Nelson, and S. Bardhan. 2012. Development of a variable source nitrogen fertilizer management strategy using enhanced efficiency nitrogen fertilizers. Soil Sci 177: 708-718.

Nash, P.R., K.A. Nelson, and P.P. Motavalli. 2013. Corn yield response to polymer- and non-coated urea placement and timings following red clover. Int. J. Plant Prod. 7 (3):373-392.

Nash, P.R., P.P. Motavalli, and K.A. Nelson. 2012. Nitrous oxide emissions from claypan soils due to nitrogen fertilizer source and tillage/fertilizer placement practices. Soil Sci. Soc. Am. J. 76:983-993.

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

Roberts, D.F., R. B. Ferguson, N.R. Kitchen, V.I. Adamchuk and J.F. Shanahan. 2012. Relationships between soil-based management zones and canopy sensing for corn nitrogen management. Agron. J. 104:119-129.

Whittaker, G., B.L. Barnhart, R. Srinivasan, and J.G. Arnold. 2014. Cost of areal reduction of gulf hypoxia through agricultural practice. Science of the Total Environ. 505:149-153.

Resume of PETER P. MOTAVALLI

Professor, Soil Nutrient Management
Dept. of Soil, Environmental and Atmospheric Sci.
School of Natural Resources
University of Missouri-Columbia
302 ABNR Bldg.
Columbia, MO 65211 USA

Telephone: (573) 884-3212
FAX: (573) 884-5070
E-mail: motavallip@missouri.edu

EDUCATION:

Ph.D., 1989, Soil Fertility and Plant Nutrition	Cornell University, Ithaca, NY
M.S., 1984, Soil Fertility and Plant Nutrition	University of Wisconsin, Madison, WI
B.S., 1982, Agronomy	University of Wisconsin, Madison, WI
B.S.F.S., 1978, Foreign Service	Georgetown University, Washington, DC

RESEARCH, EXTENSION AND TEACHING EXPERIENCE:

University of Missouri, Columbia, MO (Mar., 1999 – present). Professor of Soil Nutrient Management in the Dept. of Soil, Environmental and Atmospheric Sci.

University of Guam, Mangilao, GU (Aug., 1994 – Mar., 1999). Associate Professor of Soil Science in the Agricultural Experiment Station, College of Agriculture and Life Sciences.

Colorado State University, Ft. Collins, CO and North Carolina State University, Raleigh, NC (Feb., 1992 - Jul., 1994). Post-doctoral fellow at the Natural Resource Ecology Laboratory at Colorado State University and Department of Soil Science at North Carolina State University.

PROFESSIONAL ORGANIZATIONS:

Soil Science Society of America
American Society of Agronomy

SELECTED AWARDS AND FELLOWSHIPS:

2000 - present Adjunct Assistant Professor, Division of Plant Sciences, Univ. of Missouri
2001 - 2006 Member of Editorial Board, Journal of Plant Nutrition
2002 - 2003 New Faculty Teaching Scholar, University of Missouri
2003 Junior Faculty Research Award, Gamma Sigma Delta
2003 Chair of USDA Regional Committee on Soil Organic Matter (NCR 59)
2004 Outstanding Teaching Award, CAFNR, Univ. of Missouri
2004 Chair of Environmental Quality Division (A-5), Amer. Soc. of Agronomy
2008 - 2011 Associate Editor, Soil Science Society of America Journal
2009 Maxine Christopher Shutz Award for Distinguished Teaching, University of Missouri
2010 Inducted into the Teaching Academy, College of Agric., Food and Nat. Resources, University of Missouri
2013 Full Member, Sigma Xi Honor Society
2013 MU Excellence in Teaching with Technology Award

SELECTED RECENT PUBLICATIONS:

Nash, P.R., K.A. Nelson, and P.P. Motavalli. In press. Reducing nitrogen loss with managed drainage and polymer-coated urea. J. Environ. Qual.

Nash, P.R., K.A. Nelson, P.P. Motavalli, and S.H. Anderson. In press. Corn yield response to managed drainage and polymer-coated urea. Agron. J.

Nash, P.R., K.A. Nelson, P.P. Motavalli, M. Nathan, and C. Dudenhoeffer. In press. Reducing phosphorus loss in tile water with managed drainage in a claypan soil. J. Environ. Qual.

Nelson, K.A., P.P. Motavalli, and M. Nathan. 2014. Nitrogen fertilizer sources and application timing affects wheat and inter-seeded red clover yields on claypan soils. Agronomy 4:497-513. doi:10.3390/agronomy4040497.

Nash, P.R., K.A. Nelson, and P.P. Motavalli. 2014. Reducing nitrogen loss in subsurface tile drainage water with managed drainage and polymer-coated urea in a river bottom soil. Journal of Water Resource and Protection. 6:988-997.

Udawatta, R.P., K.A. Nelson, S. Jose, and P.P. Motavalli. 2014. Temporal and spatial differences in crop yields of a mature silver maple alley cropping system. Agron. J. 106:407-415.

Nelson, K.A., and P.P. Motavalli. 2014. Nitrogen source, drainage, and irrigation affects corn yield response in a claypan soil. Applied Engineering in Agriculture 29:875-884.

Nelson, K.A., P.P. Motavalli, and C.J. Dudenhoeffer. 2014. Cropping system affects polymer-coated urea release and corn yield response in claypan soils. Journal of Agronomy and Crop Science. 200:54-65.

Motavalli, P.P., K.A. Nelson, R.P. Udawatta, S. Jose, and S. Bardhan. 2013. Global achievements in sustainable land management. Int. Soil and Water Conserv. Res. 1:1-10.

Nash, P.R., K.A. Nelson, and P.P. Motavalli. 2013. Corn yield response to polymer- and non-coated urea placement and timings following red clover. Int. J. Plant Prod. 7 (3):373-392.

Nash, P.R., K.A. Nelson, and P.P. Motavalli. 2013. Corn yield response to timing of strip-tillage and nitrogen source applications. Agron. J. 105:623–630.

Motavalli, P.P., R.P. Udawatta, and S. Bardhan. 2013. Apparent soil electrical conductivity used to determine soil phosphorus variability in poultry litter-amended pastures. Am. J. Exp. Agric. 3(1):124-141.

Chung, S.O., K.A. Sudduth, P.P. Motavalli, and N.R. Kitchen. 2013. Relating mobile sensor soil strength to penetrometer cone index. Soil and Tillage Res. 129:9-18.

Dudenhoeffer, C., K.A. Nelson, P.P. Motavalli, B.A. Burdick, D. Dunn, and K. Goyne. 2013. Utility of phosphorus enhancers and strip-tillage for corn production. J. Agric. Sci. 5:37-46.

Nelson, K.A., P.P. Motavalli, W.E. Stevens, D. Dunn, A. Kendig, and M. Nathan. 2012. Foliar potassium fertilizer additives affect soybean response and weed control with glyphosate. Intl. J. Agron. doi:10.1155/2012/461894.

Motavalli, P.P., K.A. Nelson, and S. Bardhan. 2012. Development of a variable source nitrogen fertilizer management strategy using enhanced efficiency nitrogen fertilizers. Soil Sci 177: 708-718.

Nash, P.R., K.A. Nelson, and P.P. Motavalli. 2012. Effects of polymer-coated urea application ratios and dates on wheat and subsequent double-crop soybean . Agron. J. 104:1074–1084.

Veum, K.S., K.W. Goyne, R.J. Kremer, P.P. Motavalli 2012. Relationships among water stable aggregates and organic matter fractions under conservation management. Soil Sci. Soc. Am. J. 76:2143-2153.

Venterea, R.T., A.D. Halvorson, N.R. Kitchen, M.A. Liebig, M.A. Cavigelli, S.J. Del Grosso, P.P. Motavalli, K.A. Nelson, K.A. Spokas, B.P. Singh, C.E. Stewart, A. Ranaivoson, J. Strock, and H.P. Collins. 2012. Challenges and opportunities for mitigating nitrous oxide emissions from fertilized cropping systems. Frontiers in Ecology and the Environment 10:562-570.

Dudenhoeffer, C., K.A. Nelson, P.P. Motavalli, D. Dunn, W.E. Stevens, M. Nathan, K. Goyne, and P. Scharf. 2012. Corn production as affected by phosphorus enhancers, phosphorus sources, and lime. J. Agric. Sci. 4:137-143.

Nash, P.R., P.P. Motavalli, and K.A. Nelson. 2012. Nitrous oxide emissions from claypan soils due to nitrogen fertilizer source and tillage/fertilizer placement practices. Soil Sci. Soc. Am. J. 76:983-993.

Pengthamkeerati, P., P.P. Motavalli, and R.J. Kremer. 2011. Soil microbial biomass nitrogen and β-glucosaminidase activity response to surface compaction and poultry-litter application in a claypan soil. Applied Soil Ecology 51:79-86.

Pengthamkeerati, P., P.P. Motavalli, and R.J. Kremer. 2011. Soil microbial activity and functional diversity changed by compaction, poultry litter and cropping in a claypan soil. Applied Soil Ecology. 48:71-80.

Veum, K.S., K.W. Goyne, S.H. Holan, and P.P. Motavalli. 2011. Assessment of soil organic carbon and total nitrogen under conservation management practices in the Central Claypan Region, Missouri, USA. Geoderma. 167:188-196.

RESUME FOR KELLY A. NELSON

Research Agronomist and Professor
Division of Plant Sciences
Greenley Memorial Research Center
University of Missouri
P.O. Box 126, Hwy 156 E
Novelty, MO 63460

Tel: (660) 739-4410
Fax: (660) 739-4500
Email: nelsonke@missouri.edu
http://aes.missouri.edu/greenley/research/index.stm

EDUCATION AND TRAINING

- Ph.D. Crop and Soil Sciences, Dep. of Crop and Soil Sci., Michigan State Univ. (2000)
- M.S. Crop and Soil Sciences, Dep. of Crop and Soil Sci., Michigan State Univ. (1997)
- B.S. Plant Science, Dep. of Agronomy, Univ. of Missouri (1995)

APPOINTMENTS

- Research Agronomist & Professor, Univ. of Missouri, Novelty, MO (2013-present)
- Research Agronomist & Associate Professor, Univ. of Missouri, Novelty, MO (2007-2012)
- Research Agronomist & Assistant Professor, Univ. of Missouri, Novelty, MO (2000-2006)
- Graduate Research Assistant, Michigan State Univ., East Lansing, MI (1995-2000)
- Teaching Assistant, Michigan State Univ., East Lansing, MI (1996)

OTHER EXPERIENCE

- Research Technician, Ciba Crop Protection, Lee's Summit, MO (1994)
- Integrated Pest Management, Gypsy Moth Technician, Univ. of Missouri, Columbia, MO (1992)
- Crop and Livestock Production Assistant, Nelson Farms, Skidmore, MO (1980-1995)

HONORS AND AWARDS

- Citation of Merit, Mizzou Alumni Association of the University of Missouri (2010)
- ASABE Blue Ribbon Award, Circular Publication, Questions and answers about drainage water management for the Midwest, American Society of Agricultural and Biological Engineers (2007)
- Junior Faculty Award, Gamma Sigma Delta, Honor Society of Agriculture (2005)

SCHOLARLY SOCIETIES

- Sigma Xi
- Gamma Sigma Delta
- Honor Society of Phi Kappa Phi
- Golden Key National Honor Society
- Phi Eta Sigma Honor Society

PROFESSIONAL ORGANIZATIONS

- American Society of Agronomy
- Crop Science Society of America
- Weed Science Society of America
- North Central Weed Science Society of America
- Crop Science Society of America
- American Society of Agricultural and Biological Engineers

PATENT

- Nelson, K.A., and P.P. Motavalli. 2013. Variable product agrochemicals application management. U.S. 8594897 B2.

SERVICE

- North Central Regional Drainage Committee (NCR-217) (2003-present); Secretary 2008-2009; Chair 2009-2010
- Missouri Agriculture Leaders of Tomorrow Class XIII (ALOT) (2008-2010)
- Missouri Livestock Symposium Committee (2001-present)
- Manuscript reviewer for twelve peer-reviewed journals (2000-present)
- North Central Weed Science Society (1996-present); Membership Committee Chair (2006-2008)
- Weed Science Society of America (1996-present); Extension Committee (2001-2003)
- Missouri Wind Resources (2006-present)

SELECTED RECENT PUBLICATIONS:

Sandler, L., K. A. Nelson, and C. Dudenhoeffer. 2015. Winter wheat row spacing and alternative crop effects on relay-intercrop, double-crop, and wheat yields. Intl. J. Agron. *In press.*

Kaur, G., and K.A. Nelson. 2015. Effect of foliar boron fertilization of fine textured soils on corn yields. Agron. *In press.*

Nash, P.R., K.A. Nelson, and P.P. Motavalli. 2015. Reducing nitrogen loss with managed drainage and polymer-coated urea. J. Environ. Qual. *In press.*

Nash, P.R., K.A. Nelson, P.P. Motavalli, and S.H. Anderson. 2015. Corn yield response to managed drainage and polymer-coated urea. Agron. J. *In press.*

Nash, P.R., K.A. Nelson, P.P. Motavalli, M. Nathan, and C. Dudenhoeffer. 2014. Reducing phosphorus loss in tile water with managed drainage in a claypan soil. J. Environ. Qual. *In press.*

Nelson, K.A., P.P. Motavalli, and M. Nathan. 2014. Nitrogen fertilizer sources and application timing affects wheat and inter-seeded red clover yields on claypan soils. Agron. 4:497-513. doi: 10.3390/agronomy4040497.

Udawatta, R.P., R.J. Kremer, K.A. Nelson, S. Jose, and S. Bardhan. 2014. Soil quality of a mature alley cropping agroforestry system in temperate North America. Comm. Soil Sci. and Plant Anal. 45:2539-2551. doi: 10.1080/00103624.2014.932376.

Nash, P., K. Nelson, and P. Motavalli. 2014. Reducing nitrogen loss in subsurface tile drainage water with managed drainage and polymer-coated urea in a river bottom soil. J. Water Resource and Protection 6:988-997.

Udawatta, R.P., K.A. Nelson, S. Jose, and P.P. Motavalli. 2014. Temporal and spatial differences in crop yields of a mature silver maple alley cropping system. Agron. J. 106:407-415. doi: 10.2134/agronj2013.0429.

Nelson, K.A., P.P. Motavalli, and C.J. Dudenhoeffer. 2014. Cropping system affects polymer-coated urea release and corn yield response. J. Agron. and Crop Sci. 200:54-65. doi: 10.1111/jac.1240.

Nelson, K.A., and P.P. Motavalli. 2013. Nitrogen source and drain tile spacing affects corn yield response in a claypan soil. Applied Engineering in Agriculture. 29:875-884. doi: 10.13031/aea.29.9809.

Nelson, K.A. 2013. Crop response to the solar corridor in upstate Missouri. Agron. J. 105:1-6. doi:10.2134/agronj2012.0326.

Motavalli, P., K. Nelson, R. Udawatta, S. Jose, and S. Bardhan. 2013. Global achievements on sustainable land management. Intl. Soil and Water Conservation Res. J. 1:1-10.

Nelson, K.A., P.R. Nash, and C.J. Dudenhoeffer. 2013. Effect of nitrogen source and weed management systems on no-till corn yields. J. Agric. Sci. 5:87-96. doi: 10.5539/jas.v5n8p87.

Nash, P.R., K.A. Nelson, and P.P. Motavalli. 2013. Corn yield response to strip-tillage and polymer-coated urea application dates. Agron. J. 105:623-630. http://dx.doi.org/10.2134/agronj2012.0338

Dudenhoeffer, C.J., K.A. Nelson, P.P. Motavalli, B.A. Burdick, D. Dunn, and K. Goyne. 2013. Utility of phosphorus enhancers and strip-tillage for corn production. J. Agric. Sci. 5:37-46. doi: 10.5539/jas.v5n2p37.

Nash, P.R., K.A. Nelson, and P.P. Motavalli. 2013. Corn yield response to polymer- and non-coated urea placement and timings. Int. J. Plant Prod. 7:373-392.

Motavalli, P.P., K.A. Nelson, and S. Bardhan. 2012. Development of a variable source nitrogen fertilizer management strategy using enhanced efficiency nitrogen fertilizers. Soil Sci. 177:708-718. doi: 10.1097/SS.0b013e31827dddc1.

Nelson, K.A., P.P. Motavalli, W.E. Stevens, J.A. Kendig, D. Dunn, and M. Nathan. 2012. Foliar potassium fertilizer additives affect soybean response and weed control with glyphosate. Intl. J. Agron. doi:10.1155/2012/461894.

Venterea, R.T., A. Halvorson, N. Kitchen, M. Liebig, M. Cavigelli, S. Del Grosso, P.P. Motavalli, K.A. Nelson, K.A. Spokas, B.P. Singh, C. Stewart, A. Ranaivoson, J. Strock, and H. Collins. 2012. Technical challenges and opportunities for mitigating nitrous oxide emissions in fertilized cropping systems. Frontiers in Ecology and the Environment 10:562-570.

Harder, D.B., K.A. Nelson, and R.J. Smeda. 2012. Management options and factors affecting control of a common waterhemp (*Amaranthus rudis*) biotype resistant to protoporphyrinogen oxidase-inhibiting herbicides. Int. J. Agron. doi:10.1155/2012/514765.

Dudenhoeffer, C.J., K.A. Nelson, P.P. Motavalli, D. Dunn, W.E. Stevens, K. Goyne, M. Nathan, and P. Scharf. 2012. Corn production as affected by phosphorus enhancers, phosphorus source and lime. J. Agric. Sci. 4:137-143. doi:10.5539/jas.v4n10p137.

Senaviratne,G.M.M.M.A., R.P. Udawatta, K.A. Nelson, K. Shannon, and S. Jose. 2012. Temporal and spatial influence of perennial upland buffers on corn and soybean yields. Agron. J. 104:1356-1362.

Nash, P.R., K.A. Nelson, and P.P. Motavalli. 2012. Polymer-coated urea application ratios and timings affect wheat and double-crop soybean yields. Agron. J. 104:1074-1084.

Sandler, L., K.A. Nelson, and R.L. Smoot. 2012. Rice cultivar production and seed over winter potential in upstate Missouri. Am. J. Exp. Agric. 2:426-441.

Nelson, K.A., and R.L. Smoot. 2012. Corn hybrid response to water management practices on claypan soil. Int. J. Agron. doi:10.1155/2012/925408.

Nash, P.R., P.P. Motavalli, and K.A. Nelson. 2012. Nitrous oxide emissions from claypan soils due to nitrogen fertilizer source and tillage/fertilizer placement practices. Soil Sci. Soc. Am. J. 76:983-993.

Nelson, K. A., Meinhardt, C. G., and Smoot, R. L. 2012. Soybean cultivar response to subsurface drainage and subirrigation in Northeast Missouri. Online. Crop Management doi:10.1094/CM-2012-0320-03-RS.

Nelson, K.A., and C.G. Meinhardt. 2011. Foliar boron and pyraclostrobin effects on corn yield. Agron. J. 103:1352-1358.

Nelson, K.A., and C.G. Meinhardt. 2011. Soybean yield response to pyraclostrobin and drainage water management. Agron. J. 103:1359-1366.

Nelson, K.A., R.L. Smoot, and C.G. Meinhardt. 2011. Soybean response to drainage and subirrigation on a claypan soil in Northeast Missouri. Agron. J. 103:1216-1222.

Nelson, K.A., R.J. Smeda, and R.L. Smoot. 2011. Spring-interseeded winter rye seeding rates influence weed control and organic soybean yield. Int. J. Agron. doi:10.1155/2011/571973.

Nelson, K.A., R.E. Massey, and B.A. Burdick. 2011. Harvest aid application timing affects wheat (*Triticum aestivum* L.) and relay intercropped soybean (*Glycine max* L.) response. Agron. J. 103:851-855.